I-17 CORRIDOR PROFILE STUDY

SR 101L TO I-40

ADOT Work Task No. MPD 072B-14

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Working Paper 2: Performance System

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1. INTRODUCTION

The Arizona Department of Transportation (ADOT) is the lead agency for this corridor profile study of Interstate 17 (I-17) between SR 101L in Phoenix and I-40 in Flagstaff. This study will look at key performance measures relative to the I-17 corridor, and use those as a means to prioritize future improvements in areas that show critical deficiencies. The intent of the corridor profile program, and of the Planning to Programming process, is to conduct performance-based planning to identify areas of need and make the most efficient use of available funding to provide an efficient transportation network.

1.1. Corridor Overview

The Arizona Sun Corridor is one of eleven megapolitan areas in the United States, defined as a conglomeration of two or more intertwined metropolitan areas. The Sun Corridor megapolitan extends from Nogales to Prescott, and is similar to Indiana in area and population. The Sun Corridor is one of the fastest growing areas in the country, with I-17 playing a key role in the transportation infrastructure of its northern portion, contributing to its economic success.

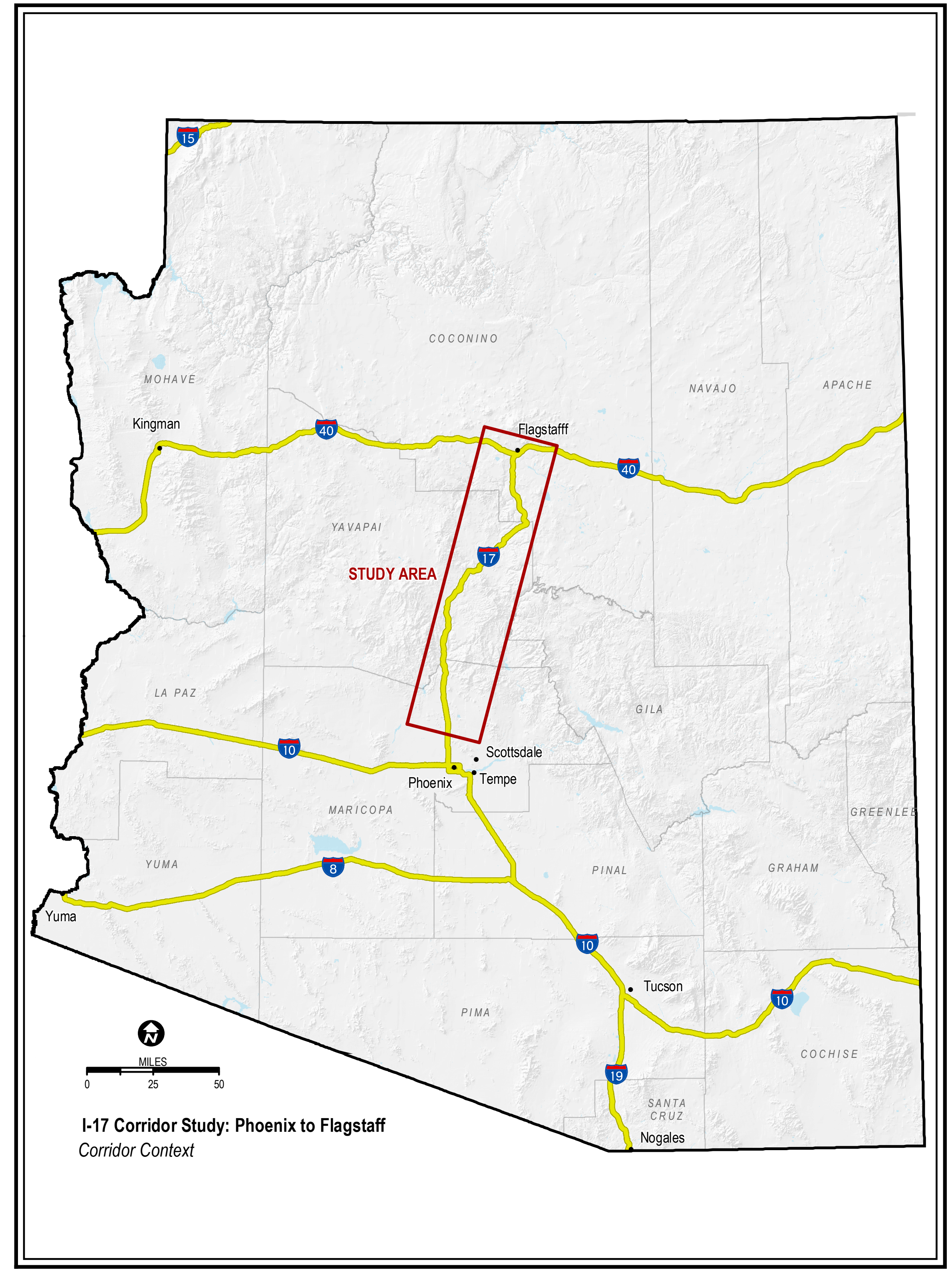
I-17 provides the most direct and fastest link between Phoenix (and I-10) and Flagstaff (and I-40) (Figure 1). I-17 provides a principal road link for national and international traffic from Phoenix Sky Harbor International Airport to Prescott, the Verde Valley, Sedona, Flagstaff, the Grand Canyon, and the Navajo and Hopi nations (Figure 2). This study builds on earlier planning efforts in developing and applying a performance-based process for prioritizing improvements to meet present and future needs in the corridor.

1.2. Corridor Study Purpose

ADOT seeks to identify a new corridor planning approach to develop strategies and tools that incorporate life-cycle cost analysis and risk assessment to measure system performance. This Corridor Profile Study, along with similar studies of I-19 and I-40, will develop a new process to:

- Inventory past improvement recommendations.
- Assess the existing performance based on quantifiable performance measures.
- Propose various solution sets to improve corridor performance.
- Identify specific projects that can provide quantifiable benefits in relation to the performance measures.
- Prioritize the projects for future implementation

Figure 1 - Study Location Map



1.3. Corridor Study Objective

The objective of this study is to identify a recommended set of prioritized potential projects for consideration in future construction programs, derived from a transparent, defensible, logical, and replicable process.

1.4. Working Paper Objectives

The objective of Working Paper # 2 is to assess the health of the corridor based on a performance system that can be applied to other corridors and allow the comparison of corridor health across corridors. The assessment of corridor needs (based on the performance system) will occur in a later working paper.

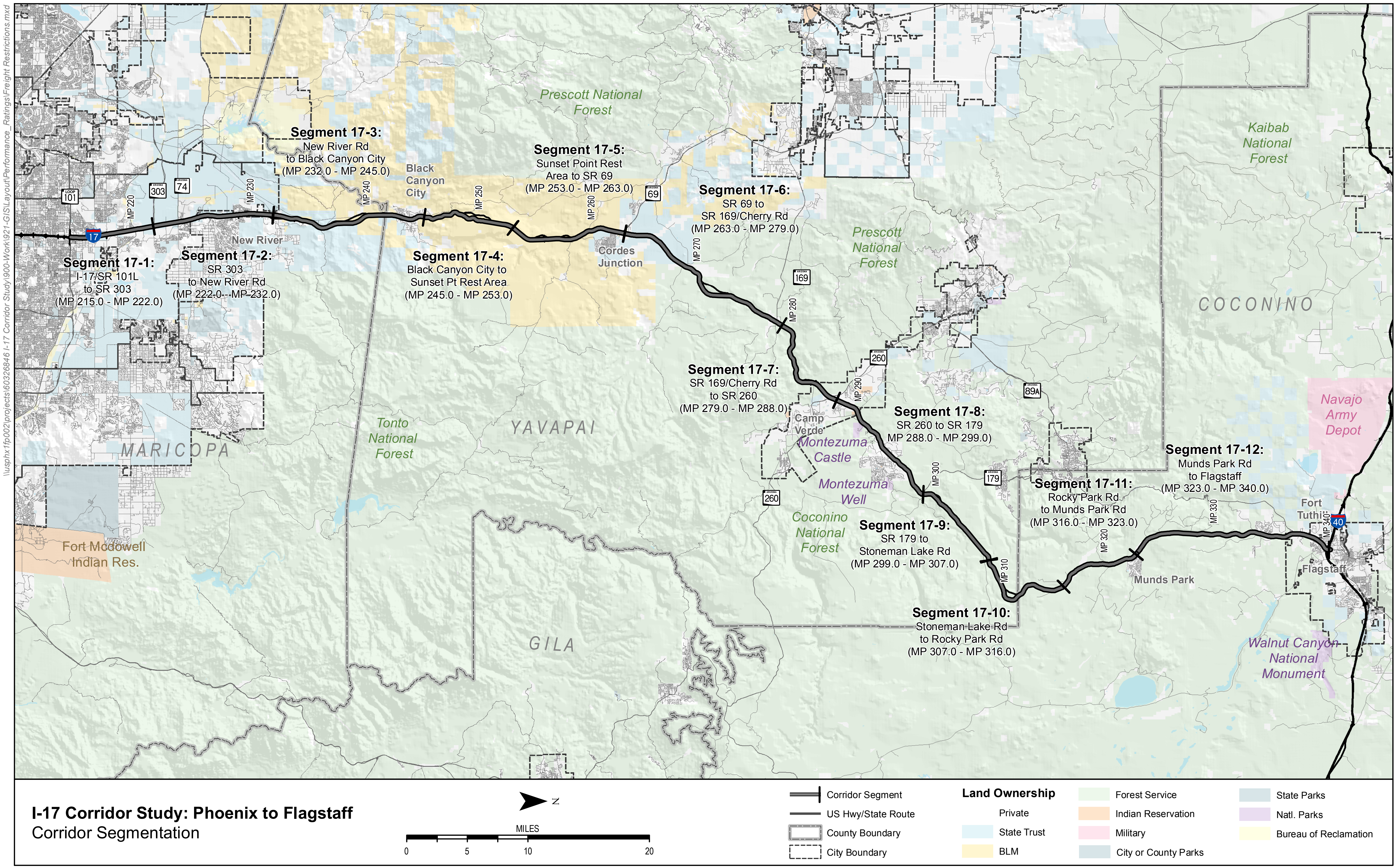
1.5. Study Location and Corridor Segments

The I-17 Corridor is 125 miles long, from SR 101L (MP 215.0) to I-40 (MP 340.0). The corridor has been divided into twelve distinct segments based on regionally significant intersecting routes, changes in topography, or natural or man-made landmarks along the corridor. The shortest segment is seven miles long and the longest, seventeen miles. Corridor Segments have been described in Table 1 below, and shown on a map in Figure 2.

Table 1 - Corridor Segmentation

Segment #	Segment Description	Character Description
Segment 1	SR101L to SR 303L (MP 215.0 to MP 222.0)	Segment 1 is generally urban/fringe-urban in nature while Segment 2 is generally rural in nature. Both are within the urbanized limits of the Phoenix Metropolitan Area in Maricopa County. Segment 1 includes six interchanges and Segment 2 includes six interchanges.
Segment 2	SR 303L to New River Road (MP 222.0 to MP 232.0)	
Segment 3	New River Road to Black Canyon City (MP 232.0 to MP 245.0)	Segment 3 is generally rural in nature, includes three interchanges, and spans both Maricopa and Yavapai Counties
Segment 4	Black Canyon City to Sunset Point Rest Area (MP 245.0 to MP 253.0)	Segment 4 is rural in nature, includes significant changes in topography, two interchanges, and is within Yavapai County.
Segment 5	Sunset Point Rest Area to SR 69 (MP 253.0 to MP 263.0)	Segment 5 is rural in nature, includes changes in topography, three interchanges, and is located within Yavapai County.
Segment 6	SR 69 to SR 169 (MP 263.0 to MP 279.0)	Segment 6 is rural in nature, passes through generally rolling terrain, includes two interchanges, and is located within Yavapai County.
Segment 7	SR 169 to SR 260 (MP 279.0 to MP 288.0)	Segment 7 goes through significant topography and elevation changes, is rural in nature, includes two interchanges, and is within Yavapai County.
Segment 8	SR 260 to SR 179 (MP 288.0 to MP 299.0)	Segment 8 passes through gradual elevation changes, is rural in character, includes three interchanges, and is located within Yavapai County.
Segment 9	SR 179 to Stoneman Lake Road (MP 299.0 to MP 307.0)	Segment 9 is rural in nature, includes changes in topography, one interchange, and is located within Yavapai County.
Segment 10	Stoneman Lake Road to Rocky Park Road (MP 307.0 to MP 316.0)	Segment 10 is rural in nature, includes changes in topography, one interchange, and spans both Yavapai and Coconino Counties.
Segment 11	Rocky Park Road to Munds Park Road (MP 316.0 to MP 323.0)	Segment 11 is rural in nature, includes three interchanges, and is located within Coconino County.
Segment 12	Munds Park Road to I-40 (MP 323.0 to MP 340.0)	Segment 12 transitions from a rural setting to a fringe-urban setting, includes four interchanges, is located within Coconino County, and extends into the City of Flagstaff.

Figure 2 - Project Vicinity/Segmentation Map

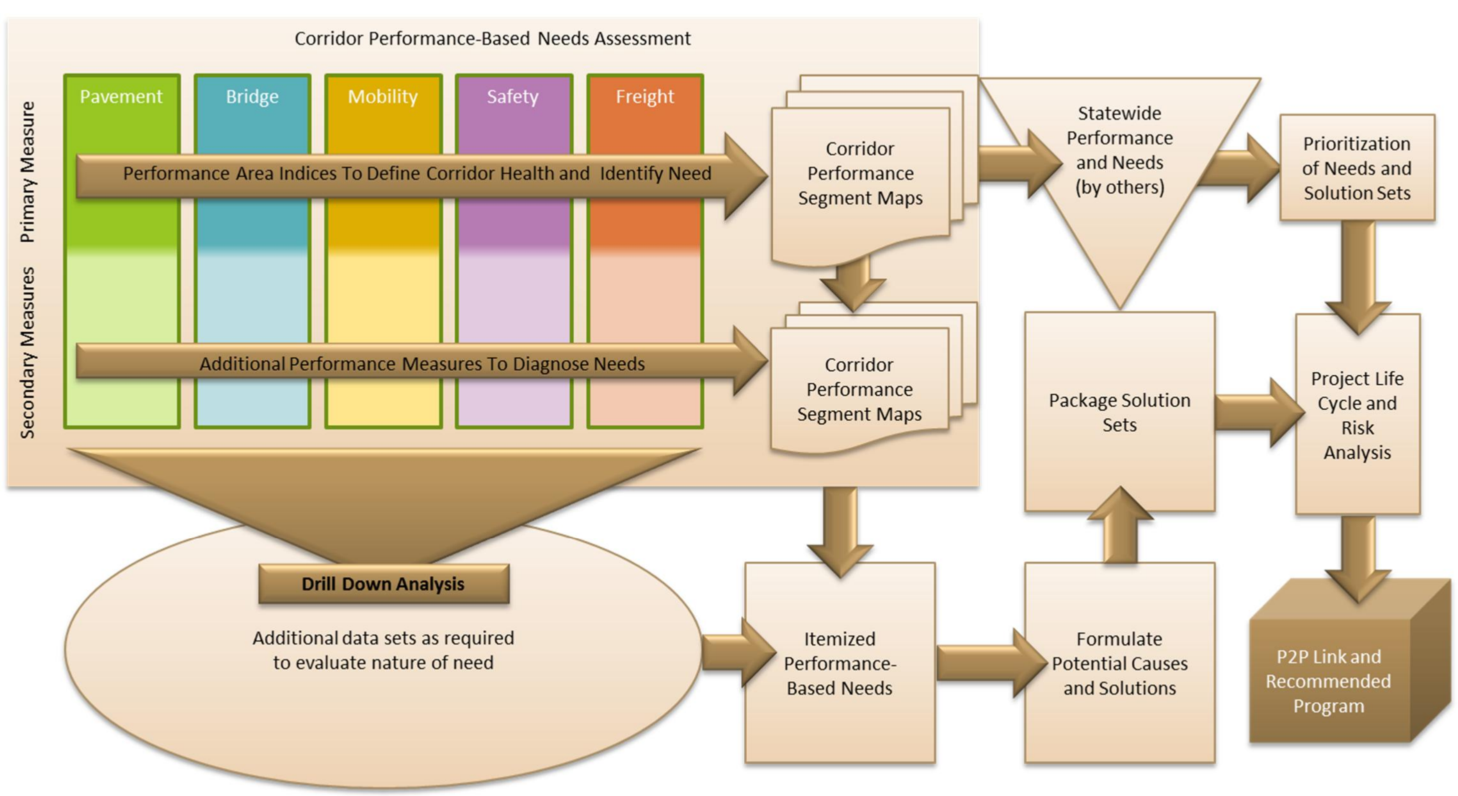


2. PERFORMANCE FRAMEWORK

2.1. Performance Framework Overview

An objective of the ADOT Corridor Profile Studies is to use a performance-based process to define baseline corridor performance, diagnose corridor needs and deficiencies, develop corridor solutions, and prioritize strategic corridor investments. In support of this study objective, a framework for the performance-based process was developed through a collaborative process involving ADOT and the consultant teams for the I-17, I-19, and I-40 Corridor Profile Studies. In the performance framework illustrated in Figure 3, baseline performance is evaluated using primary and secondary performance measures to define the health of the corridor and identify locations that warrant further diagnostic investigation to define needs and deficiencies. Needs and deficiencies are defined as the difference in baseline corridor performance compared to established performance goals. Corridor improvements and strategies are characterized in the ADOT transportation programming process as investment options for preserving, modernizing, and expanding corridor infrastructure to improve corridor performance. Improvement priorities are evaluated using ADOT's Planning to Programing (P2P) Link processes.

Figure 3 - Corridor Profile Performance Framework



Five performance areas were defined to guide the performance-based corridor analyses. The five performance areas include:

- Pavement performance
- Bridge performance
- Mobility performance
- Safety performance
- Freight performance

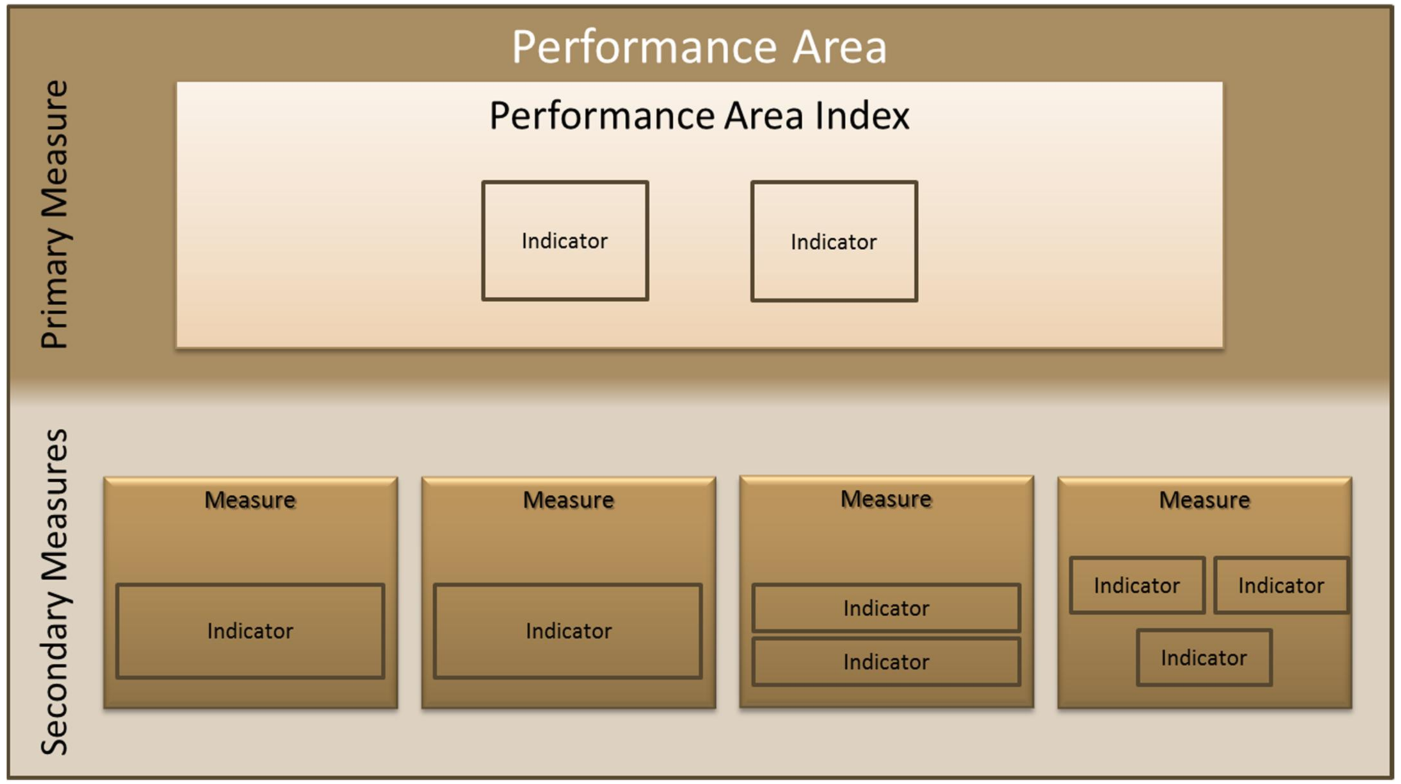
These performance areas reflect the seven *Moving Ahead for Progress in the 21st Century* (MAP-21) national performance goals which are listed below.

- Safety: To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
- Infrastructure condition: To maintain the highway infrastructure asset system in a state of good repair
- Congestion reduction: To achieve a significant reduction in congestion on the National Highway System
- System reliability: To improve the efficiency of the surface transportation system
- Freight movement and economic vitality: To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
- Environmental sustainability: To enhance the performance of the transportation system while protecting and enhancing the natural environment
- Reduced project delivery delays: To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion

The national performance goals listed above were considered in the development of ADOT's P2P process for linking transportation planning to capital improvement programming and project delivery. The P2P process includes the preparation of annual transportation system performance reports using the same five performance areas listed above. Therefore, the performance areas will be consistent between the statewide performance reports and the corridor profile studies.

A generalized framework for each performance area is illustrated in Figure 4.

Figure 4 - Performance Area Measures



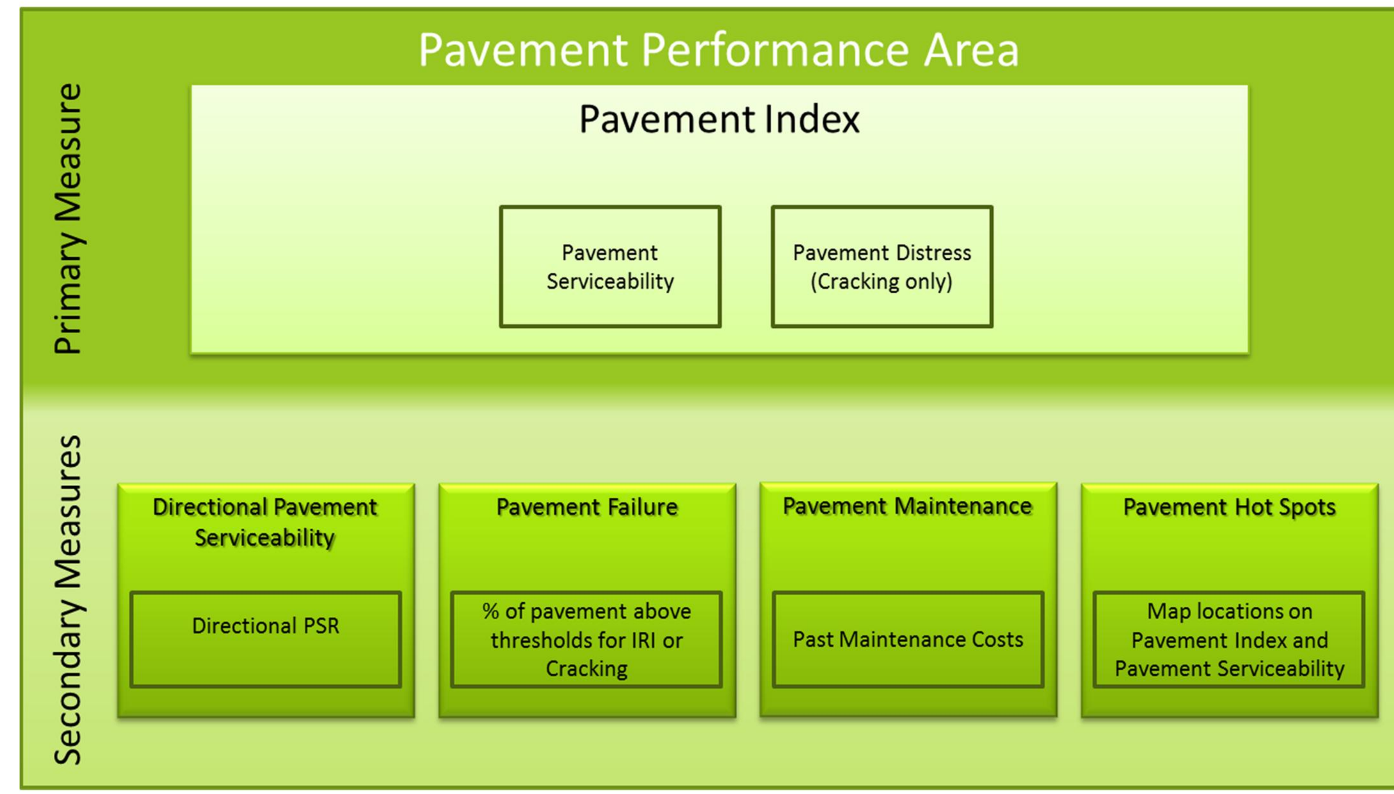
The guidelines for performance measure development are listed below:

- Indicators (or performance measures) for each performance area should be developed for relatively homogeneous corridor segments.
- Performance measures for each performance area should be tiered, consisting of primary measure(s) and secondary measure(s).
- Primary and secondary measures will assist in identifying those corridor segments that warrant in-depth diagnostic analyses to identify performance-based needs and a range of corrective actions known as solution sets.
- One or more primary performance measures should be used to develop a Performance Area Index to communicate the overall health of a corridor and its segments for each performance area. The Performance Index should be a single numerical index that is quantifiable, repeatable, scalable, and capable of being mapped. Primary performance measures should be transformed into a performance index using mathematical or statistical methods to combine one or more data fields from an available ADOT database.
- One or more secondary performance measures should be used to provide additional details to define corridor locations that warrant further diagnostic analysis. Secondary performance measures may include the individual measures used to calculate the Performance Index, other performance data, and/or “hot spot” features.

2.2. Pavement Performance Area

The Pavement Performance Area consists of a primary measure (Pavement Index) and two secondary measures, as shown in Figure 5, to assess the condition of the existing pavement along the corridor. The performance system was developed in collaboration with ADOT Materials Group. The results of the Pavement Performance Area for I-17 are presented in Chapter 3. A detailed methodology for calculating the performance measures is provided in the Appendix.

Figure 5 – Pavement Performance Area



For the Pavement Performance Area, only mainline pavement was included in the calculation. Pavement condition data for ramps, frontage roads, crossroads, etc. was not included. Detailed information related to the calculations for the Pavement Performance area is included in the Appendix.

2.2.1 Primary Measure

The Pavement Index is calculated based on the use of two pavement condition ratings from the ADOT Pavement Database. The two ratings are the International Roughness Index (IRI) and the Cracking Rating. The calculation of the Pavement Index uses a combination of these two ratings. These two ratings were used for the primary measure since they represent the data used by ADOT Materials Group to assess the need for pavement rehabilitation.

The IRI is a measurement of the pavement roughness based on field-measured longitudinal roadway profiles. To facilitate the calculation of the index, the IRI rating was converted to a Pavement Serviceability Rating (PSR) using the following equation:

$$PSR = 5 * e^{-0.0038*IRI}$$

The Cracking Rating is a measurement of the amount of surface cracking based on a field-measured area of 1,000 square feet that serves as a sample for each mile. To facilitate the calculation of the index, the Cracking Rating was converted to a Pavement Distress Index (PDI) using the following equation:

$$PDI = 5 - (0.345 * C^{0.66})$$

Both the PSR and PDI use a 0 to 5 scale with 0 representing the lowest performance and 5 representing the highest performance. The performance thresholds shown in the table below were used for the PSR and PDI.

	IRI (PSR)	Cracking (PDI)
Good	<75 (>3.75)	<7 (>3.75)
Fair	75 - 117 (3.20 - 3.75)	7 - 12 (3.22 - 3.75)
Poor	>117 (<3.20)	>12 (<3.22)

The PSR and PDI are calculated for each 1-mile section of roadway. If the PSR or PDI falls into a poor rating (<3.2) for a 1-mile section, then the score for that 1-mile section is entirely (100%) based on the lower score (either PSR or PDI). If neither PSR or PDI fall into a poor rating for a 1-mile section, then the score for that 1-mile section is based on a combination of the lower rating (70% weight) and the higher rating (30% weight). The end result is a score between 0 and 5 for each direction of travel of each mile of roadway based on a combination of both the PSR and the PDI.

The Pavement Index for each segment is a weighted average of the directional ratings based on the number of travel lanes. Therefore, the condition of a section with more travel lanes will have a greater influence on the resulting segment Pavement Index than a section with fewer travel lanes. The performance thresholds for the Pavement Index are as follows:

- Good: > 3.75
- Fair: 3.20 – 3.75
- Poor: < 3.20

2.2.2 Secondary Measures

Two secondary measures will be evaluated:

- Directional Pavement Serviceability
- Pavement Failure

Directional Pavement Serviceability

Similar to the Pavement Index, the Directional Pavement Serviceability is calculated as a weighted average (based on number of lanes) for each segment. However, this rating will only utilize the PSR and will be calculated separately for each direction of travel. The PSR uses a 0 to 5 scale with 0 representing the lowest performance and 5 representing the highest performance. The purpose of this secondary measure is to assess the condition of the pavement in each direction of travel. The thresholds for the Directional Pavement Serviceability are as follows:

- Good: > 3.75
- Fair: 3.20 – 3.75
- Poor: < 3.20

Pavement Failure

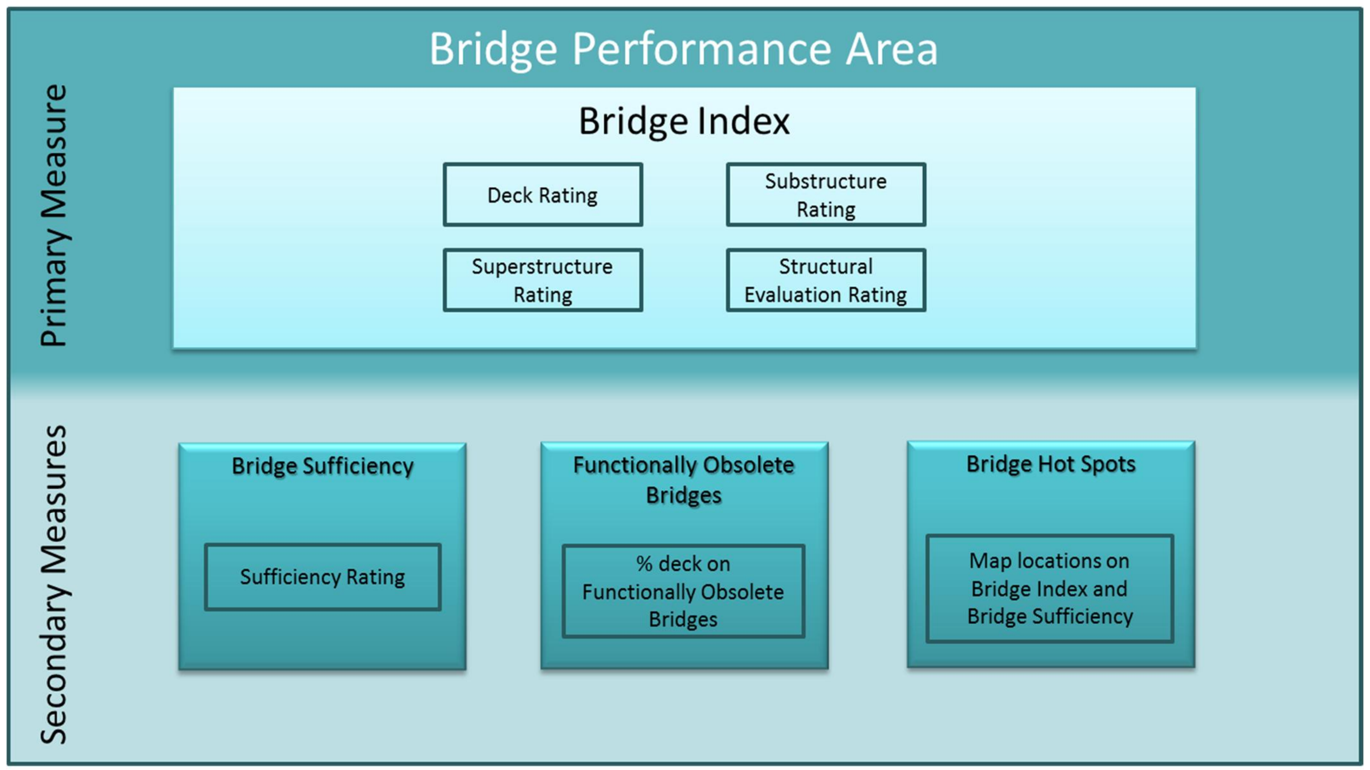
This secondary measure calculates the percentage of pavement area for each segment that is rated above the failure thresholds for IRI or Cracking, as established by ADOT Materials Group (IRI > 105 or Cracking > 15). The pavement area within each segment that has been identified in poor condition will be totaled and divided by the total pavement area for the segment to calculate the percentage of pavement area in poor condition for each segment. Based on the data from the I-17, I-19, and I-40 corridors, the thresholds for the Pavement Failure are as follows:

- Better than average performance: < 5%
- Average performance: 5% - 20%
- Worse than average performance: > 20%

2.3. Bridge Performance Area

The Bridge Performance Area consists of a primary measure (Bridge Index) and two secondary measures, as shown in Figure 6, to assess the condition of the existing bridges along the corridor. The performance system was developed in collaboration with ADOT Bridge Group. The results of the Bridge Performance Area for I-17 are presented in Chapter 3. A detailed methodology for calculating the performance measures is provided in the Appendix.

Figure 6 – Bridge Performance Area



For the Bridge Performance Area, only bridges that carry mainline traffic or bridges that cross the mainline were included in the calculation. Bridges that do not carry mainline traffic or do not cross the mainline were not included. Detailed information related to the calculations for the Bridge Performance area is included in the Appendix.

2.3.1 Primary Measure

The Bridge Index is calculated based on the use of four bridge condition ratings from the ADOT Bridge Database, also known as the Arizona Bridge Information and Storage System (ABISS). The four ratings include the Deck Rating, Substructure Rating, Superstructure Rating, and Structural Evaluation Rating. These ratings are based on inspection reports and are used to establish the structural adequacy of the bridge. The condition of each individual bridge is established by using the lowest of these four ratings. The use of these ratings, and the use of the lowest rating, is consistent with the approach used by ADOT Bridge Group to assess the need for bridge rehabilitation.

Each of the four condition ratings use a 0 to 9 scale with 0 representing the lowest performance and 9 representing the highest performance. As defined by ADOT Bridge Group, a rating of 7 or above represents “good” performance, a rating of 5 or 6 represents “fair” performance, and a rating of 4 or below represents “poor” performance.

In order to report the Bridge Index for each corridor segment, the Bridge Index for each segment is a weighted average condition rating based on the deck area for each bridge. Therefore, the condition of a larger bridge will have a greater influence on the resulting segment Bridge Index than a smaller bridge. The resulting Bridge Index is based on a 0 to 9 scale with 0 representing the lowest performance and 9 representing the highest performance. The performance thresholds for the Bridge Index are as follows:

- Good: > 6.5
- Fair: 5.0 – 6.5
- Poor: < 5.0

2.3.2 Secondary Measures

Two secondary measures will be evaluated:

- Bridge Sufficiency Rating
- Functionally Obsolete Bridges

Bridge Sufficiency Rating

The Sufficiency Rating for each bridge is available from the ADOT Bridge Database. The Sufficiency Rating is calculated by using numerous factors to obtain a numeric value which is indicative of bridge sufficiency to remain in service. The result of this method is a percentage in which 100 percent would represent an entirely sufficient bridge and zero percent would represent an entirely insufficient or deficient bridge. The factors that contribute to the Sufficiency Rating include structural adequacy and safety, serviceability and functional obsolescence, and essentiality for public use. The Bridge Sufficiency rating was used as a secondary measure (instead of a primary measure) since it includes a broad range of information to assess the condition of the bridge including the amount of traffic and the length of detour, but does not directly relate to the structural adequacy of the bridge.

Similar to the Bridge Index, the Bridge Sufficiency Rating is calculated as a weighted average (based on deck area) for each segment. The Sufficiency Rating is a scale of 0 to 100 with 0 representing the lowest performance and 100 representing the highest performance. The performance thresholds for the Bridge Sufficiency Rating are as follows:

- Good: > 80
- Fair: 50 – 80
- Poor: < 50

Functionally Obsolete Bridges
Functionally Obsolete means that the design of a bridge is no longer functionally adequate for its current use, such as a lack of shoulders or the inability to handle current traffic volumes. Functionally Obsolete does not directly relate to the structural adequacy.

The percentage of deck area on functionally obsolete bridges is calculated for each segment. The deck area for each bridge within each segment that has been identified as functionally obsolete will be totaled and divided by the total deck area for the segment to calculate the percentage of deck area on functionally obsolete bridges for each segment. Based on the data from the I-17, I-19, and I-40 corridors, the thresholds for the Functionally Obsolete Bridges are as follows:

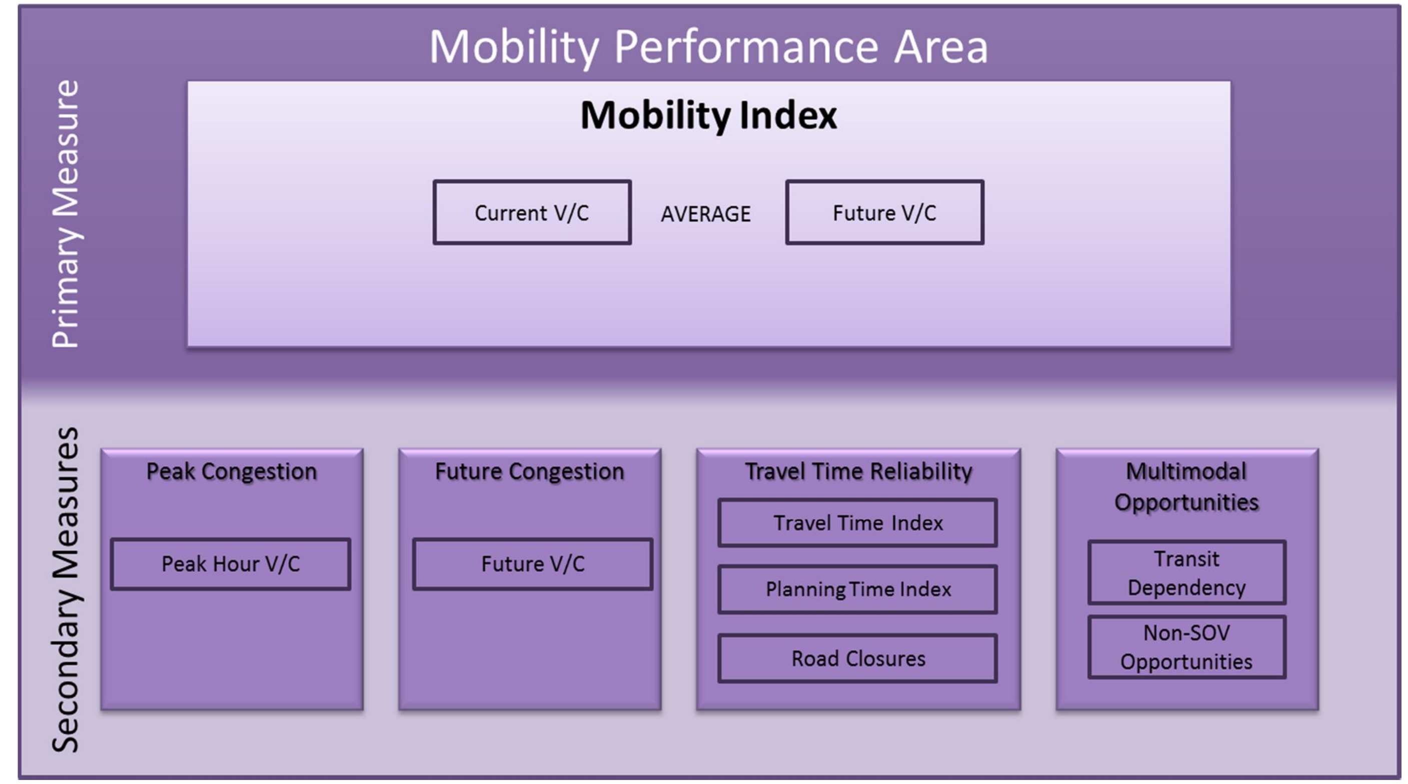
- Better than average performance: < 15%
- Average performance: 15% - 45%
- Worse than average performance: > 45%

2.4. Mobility Performance Area

The Mobility Performance Area consists of a primary measure (Mobility Index) and four secondary measures, as shown in Figure 7, to assess the traffic operational conditions along the corridor. The results of the Mobility Performance Area for I-17 are presented in Chapter 3. A detailed methodology for calculating the performance measures is provided in the Appendix.

The Mobility Performance Area Index estimates the levels and types of congestion that occur throughout the corridor based on available data such as annual average daily traffic (AADT), projected growth rates from the Arizona Travel Demand Model (AZTDM), travel time, and road closures. These datasets were used to develop primary and secondary measurements that were applied to the corridor to determine the mobility rating of each segment of the corridor.

Figure 7 – Mobility Performance Area



2.4.1 Primary Measure

The Mobility Index is an average of the current volume to capacity (V/C) ratio and the projected 2035 V/C ratio for each segment throughout the corridor. By using the average of the current and future year, this index measures both the current level of daily congestion and the future level of congestion that could occur in approximately twenty years if no capacity improvements were made to the corridor.

The current V/C ratio for each segment is calculated using the 2013 AADT volume and dividing that value by the total Level of Service (LOS) 'E' capacity volume, as defined by the Florida Department of Transportation (FDOT) LOS Handbook Tables. Each corridor contains a series of Highway Performance Monitoring System (HPMS) stations that collect traffic volume data for that specific location. The AADT volume from each HPMS station within each segment will be used to calculate an average AADT for each segment within the corridor.

The overall segment capacity is defined based on the characteristics of each segment including the number of lanes, terrain type, and facility type (urban or rural), which are correlated to a generalized capacity volume in the FDOT LOS Handbook Tables.

The future V/C ratio for each segment is calculated using the 2035 AADT volume for each segment and dividing that value by the LOS 'E' capacity volume as defined by the FDOT LOS Handbook Tables. The capacity volumes used in this calculation are the same values as defined in the current V/C ratio to help understand how projected volumes will operate in the existing corridor thus representing a "No-Build" condition. The future AADT volumes are generated by applying an annual compound growth rate (ACGR) to each 2013 AADT segment volume. The ACGR was defined using the AZTDM.

The rating thresholds defined for the Mobility Index are based on the current ADOT Roadway Design Guidelines. These standards define acceptable limits for LOS based on the facility type. The following thresholds were assigned to each segment:

Urban and Fringe Urban Environments
Good (LOS A-C): V/C ≤ 0.71
Fair (LOS D): V/C > 0.71 & ≤ 0.89
Poor (LOS E-F): V/C > 0.89

Rural Environments
Good (LOS A-B): V/C ≤ 0.56
Fair (LOS C): V/C > 0.56 & ≤ 0.76
Poor (LOS D-F): V/C > 0.76

2.4.2 Secondary Measures

Four secondary measures will be evaluated:

- Existing Peak Hour Congestion
- Future Congestion
- Travel Time Reliability
- Multimodal Opportunities

Existing Peak Hour Congestion
Peak Congestion is defined as the peak hour V/C ratio in both directions of the corridor. This measure provides an understanding of the directional operating characteristics of the corridor during the existing peak hour. The peak hour V/C is calculated by dividing the directional design hour volume (DHV) by the directional LOS 'E' capacity volume as defined by the FDOT Generalized LOS Handbook Tables. The DHV is calculated by applying directional K Factors to the directional 24hr AADT volumes for each segment of the corridor. K Factors for each segment will be defined from the existing HPMS data. Similar to the current daily V/C calculations, the directional AADT for each segment will be calculated from the directional 24 hour volumes from each HPMS count station within each segment. The segment capacity is defined based on the characteristics of each segment including number of lanes, terrain type, and facility type (urban or rural), which correlate to a generalized capacity volume in the FDOT tables.

The rating thresholds defined for the Existing Peak Hour Congestion secondary measure are based on the current ADOT Roadway Design Guidelines and are the same as the thresholds defined for the Mobility Index described Section 2.4.1.

Future Congestion
Future Congestion is a measurement of the future V/C ratio and identifies how the corridor will operate in the future from a mobility and congestion standpoint. This measure is the same value used in the calculation of the Mobility Index described in Section 2.4.1.

The rating thresholds defined for the Future Congestion secondary measure are based on the current ADOT Roadway Design Guidelines and are the same as the thresholds defined for the Mobility Index in Section 2.4.1.

Travel Time Reliability
The travel time reliability will be assessed by investigating three performance measures: Directional Closures, Travel Time Index, and Planning Time Index.

Directional Closures
The highway closures that occur at any point along the corridor are documented through the ADOT Highway Condition Reporting System (HCRS) dataset. Directional closures are defined as the average number of times a segment of the corridor was closed per mile in a specific direction of travel per year. A weighted average will be applied to each closure within each segment that takes into account the distance over which a specific occurrence spans.

The rating thresholds defined for the Directional Closures secondary measure are based on the average number of closures per mile per year that occur on the nine statewide significant corridors that have been identified by ADOT for Corridor Profile Studies: I-8, I-10, I-17, I-19, I-40, US 93, US/SR 95, and parts of US 60, US 70, SR 87, US 191, SR 260, SR 277, and SR 377. The following thresholds represent the average for closure occurrences across those corridors:

Good: ≤ 0.26 occurrences per mile per year
Fair: > 0.26 occurrences & ≤ 1.53 occurrences per mile per year
Poor: > 1.53 occurrences per mile per year

Directional Travel Time Index
The Travel Time Index (TTI) is the relationship of the average peak period travel time to the free-flow travel time. The TTI represents recurring delay that occurs along a corridor.

The TTI can be converted into a speed-based index by recognizing that speed is equal to distance traveled divided by travel time. The speed-based TTI is calculated using the following formula:

TTI = Free-Flow Speed / Observed Average Peak Period Speed

The free-flow speed is assumed to be the posted speed limit. The 2013 American Digital Cartography, Inc. HERE (formerly NAVTEQ) database includes data received via Bluetooth technology from motorists traveling throughout the corridor for four time periods throughout the day (AM Peak, Mid-Day, PM Peak, and Off-peak). The slowest travel speed of the four time periods was used for the TTI for that data point. The average TTI was calculated within each segment based on the number of data points collected.

Based on national research and coordination with ADOT, the following thresholds were applied to the TTI for the Mobility Performance Area:

Good: < 1.15
Fair: ≥ 1.15 & < 1.33
Poor: ≥ 1.33

Directional Planning Time Index
The Planning Time Index (PTI) represents the amount of time over and above the expected travel time that should be planned for, to make an on-time trip on a consistent basis. The PTI is the ratio of total travel time needed for 95 percent on-time arrival to free-flow travel time. The PTI reflects the extra buffer time needed for on-time arrival while accounting for non-recurring delay such as crashes, inclement weather, and construction activities.

The PTI was converted to a speed-based index by recognizing that speed is equal to distance traveled divided by travel time. The inverse relationship between travel time and speed means that the 95th percentile travel time corresponds to the 5th percentile travel speed. The speed-based PTI is calculated using the following formula:

PTI = Free-Flow Speed / Observed 5th Percentile Lowest Speed

The free-flow speed is assumed to be the posted speed limit. Similar to the TTI, the PTI utilizes HERE data provided by ADOT that is collected over four times of day (AM Peak, Mid-Day, PM Peak, and Off-peak). The highest value of the four time periods was used for the PTI for that data point. The average PTI was calculated within each segment based on the number of data points collected.

Based on national research and coordination with ADOT, the following thresholds were applied to the PTI for the Mobility Performance Area:

Good: < 1.30
Fair: ≥ 1.30 & < 1.50
Poor: ≥ 1.50

<u>*Multimodal Opportunities*</u>
Multimodal opportunities reflect the characteristics of the corridor in terms of likelihood to use either transit or other non-single occupancy vehicle options for trips throughout the corridor.

Transit Dependency
Transit dependency will be determined at the census tract level based on population characteristics associated with tracts within a one-mile radius of the corridor. Populations that have zero or one automobile households and households where the total income level is below the federally defined poverty level are considered transit dependent. Based on US Census data, the tracts will be analyzed to determine how their population compared to the statewide averages of those characteristics.

The rating thresholds defined for the overall transit dependency of each census tract are a combination of both transit dependent characteristics as follows:

Good: Tracts with both zero and one automobile households and population in poverty below the statewide average
Fair: Tracts with either zero and one vehicle household OR population in poverty percentages within the statewide average
Poor: Tracts with both zero and one automobile households and population in poverty above the statewide average

Non-Single Occupancy Vehicle Trips
Non-single occupancy vehicle trips represent the number of trips that are taken in a corridor by vehicles carrying more than one passenger. The percentage of non-single occupancy vehicle trips in a corridor gives an indication of travel patterns along a section of roadway that could benefit from additional multimodal options in the future. The number of non-single occupancy vehicle trips in a 24 hour period will be estimated for each segment of the corridor using the AZTDM.

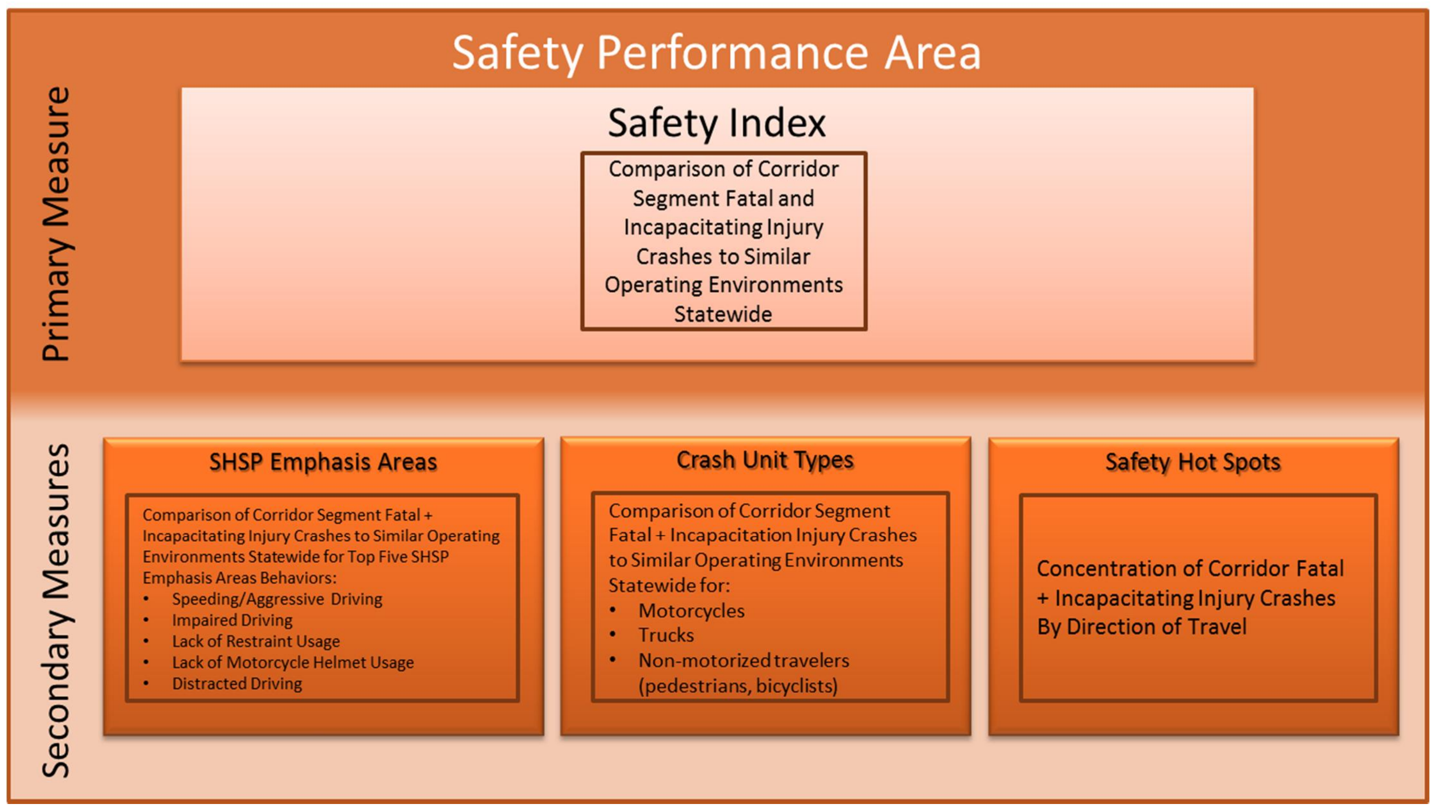
The rating thresholds defined for non-single occupancy vehicle trips are based on the percentage of non-single occupancy vehicle trips across the previously identified nine ADOT statewide significant corridors. The following thresholds represent statewide averages across those corridors:

Good: ≥ 17% of trips are Non-SOV trips
Fair: >11% & ≤ 17% of trips are Non-SOV trips
Poor: < 11% of trips are Non-SOV trips

2.5. Safety Performance Area

The safety performance area consists of a primary measure (Safety Index) and three secondary measures as illustrated in Figure 8. All measures relate to crashes that result in fatal and incapacitating injuries, as these types of crashes are the emphasis of the ADOT Strategic Highway Safety Plan, Federal Highway Administration (FHWA), and MAP-21. The results of the Safety Performance Area for I-17 are presented in Chapter 3. A detailed methodology for calculating the performance measures is provided in the Appendix.

Figure 8 - Safety Performance Area



2.5.1 Primary Measure

The Safety Index is a safety performance measure based on the bi-directional (i.e., both directions combined) frequency and rate of fatal and incapacitating injury crashes, the relative cost of those types of crashes, and crash occurrences on similar roadways in Arizona. The crash data includes the timeframe from January 2009 to December 2013. According to ADOT's 2010 Highway Safety Improvement Program Manual, fatal crashes have an estimated cost that is 14.5 times the estimated cost of incapacitating injury crashes ($5.8 million compared to $400,000).

The Combined Safety Score (CSS) is an interim measure that combines fatal and serious injury crashes into a single value. The CSS is calculated using the following generalized formula:

*CSS = 14.5 * (Normalized Fatal Crash Rate + Frequency) + (Normalized Incapacitating Injury Crash Rate + Frequency)*

Because crashes vary depending on the operating environment of a particular roadway, statewide CSS was developed for similar operating environment including functional classification, urban vs. rural setting, number of travel lanes, and traffic volumes. To determine the Safety Index of a particular segment, the segment CSS was compared to the average statewide CSS with similar operating environments in rural and urban environments.

The Safety Index is calculated using the following formula:

Safety Index = Statewide Similar Operating Environment CSS / Segment CSS

The average annual Safety Index for a segment is compared to the statewide similar operating environment annual average, with one standard deviation from the statewide average forming the scale break points.

With the Safety Index, the higher the Safety Index is above 1.0, the more the safety performance is above average (i.e., better safety performance) for a particular segment compared to the statewide similar operating environment average.

The scale for rating the Safety Index depends on the operating environments selected for a particular corridor. In the case of the I-17 corridor between MP 215 and MP 340, the scale for rating the Safety Index is:

- Above average performance: > 1.24
- Average performance: 0.76 - 1.24
- Below average performance: < 0.76

When setting the scale limits, it should be noted that the lower bound of the Safety Index is zero (which represents an infinite number of crashes on a segment). There is no upper bound for the Safety Index. As the number of crashes on a segment approaches zero, the Safety Index becomes more heavily influenced by the segment length and traffic volume. To mitigate the influence of an unlimited Safety Index, an upper limit is set that puts the midpoint of the average Safety Index equidistant between the upper limit and zero. Therefore, the upper limit is set at 2.0.

2.5.2 Secondary Measures

Three secondary measures will be evaluated:

- Strategic Highway Safety Plan (SHSP) Behavior Emphasis Areas
- SHSP Crash Unit Type Emphasis Areas
- Crash Frequency Hot Spots

Strategic Highway Safety Plan (SHSP) Behavior Emphasis Areas

ADOT's 2014 SHSP identifies several emphasis areas for reducing fatal and incapacitating injury crashes. The top five SHSP emphasis areas relate to the following driver behaviors:

- Speeding and aggressive driving
- Impaired driving
- Lack of restraint usage
- Lack of motorcycle helmet usage
- Distracted driving

To develop a performance measure that reflects these five emphasis areas, crashes that involve at least one of the emphasis area driver behaviors as a percent of total crashes on the segment is compared to similar crash percentages on statewide roads with similar operating environments.

To avoid large variations in a performance measure due to a small variation in crash frequency (i.e., one or two crashes) where the sample size is small, the five behavior emphasis areas are combined to identify fatal and incapacitating injury crashes that exhibit one or more of the behavior emphasis areas.

The SHSP behavior emphasis areas performance is calculated using the following formula:

% Crashes Involving SHSP Behavior Emphasis Areas = Segment Crashes Involving SHSP Behavior Emphasis Areas / Total Segment Crashes

The percentage of total crashes involving SHSP behavior emphasis areas for a segment is compared to the statewide percentages on roads with similar operating environments. One standard deviation from the statewide average percentage forms the scale break points.

When assessing the performance of the SHSP behavior emphasis areas, the higher the frequency of crashes involving SHSP behavior emphasis areas is above the statewide average implies lower levels of segment performance. Thus, lower performance ratings are better which is opposite from the Safety Index where higher performance ratings are better.

The scale for rating the SHSP behavior emphasis areas performance depends on the crash history on similar statewide operating environments. In the case of the I-17corridor between MP 215 and MP 340, the scale for rating the SHSP behavior emphasis areas performance is:

- Above average frequency: > 51% for rural segments and > 55% for urban segments
- Average frequency: 44%-51% for rural segments and 35%-55% for urban segments
- Below average frequency: < 44% for rural segments and < 35% for urban segments

SHSP Crash Unit Type Emphasis Areas

ADOT's SHSP also identifies emphasis areas that relate to the following "unit-involved" crashes:

- Heavy vehicle (trucks)-involved crashes
- Motorcycle-involved crashes
- Non-motorized traveler (pedestrians and bicyclists)-involved crashes

To develop a performance measure reflecting the unit emphasis areas, the relative frequencies of the crash unit types on a segment is compared to similar unit crashes on roads with similar operating environment statewide in a process similar to how the Safety Index is developed.

To avoid large variations in a performance measure due to a small variation in crash frequency (i.e., one or two crashes) where the sample size is small, the unit crash data was evaluated and mapped to determine if the sample size is sufficiently large. Unit crash data for the I-17 corridor between MP 215 and MP 340, was reviewed and it was determined that the sample size was sufficient for truck-involved and motorcycle-involved crashes.

The SHSP crash unit type emphasis areas performance is calculated using the following formula:

% Crashes Involving SHSP Crash Unit Type Emphasis Areas = Segment Crashes Involving SHSP Crash Unit Type Emphasis Areas / Total Segment Crashes

The percentage of total crashes involving SHSP crash unit type emphasis areas for a segment is compared to the statewide percentages on roads with similar operating environments. One standard deviation from the statewide average percentage forms the scale break points.

When assessing the performance of the SHSP crash unit type emphasis areas, the higher the percentage of crashes involving SHSP crash unit type emphasis areas is above the statewide average implies lower levels of segment performance. Thus, lower performance ratings are better which is opposite from the Safety Index where higher performance ratings are better.

The scale for rating the SHSP crash unit type emphasis areas performance depends on the crash history on similar statewide operating environments. In the case of the I-17 corridor between MP 215 and MP 340, the scale for rating the truck related crash emphasis area is:

- Above average frequency: > 16% for rural segments and > 6% for urban segments
- Average frequency: 11%-16% for rural segments and 2%-6% for urban segments
- Below average frequency: < 11% for rural segments and < 2% for urban segments

In the case of the I-17 corridor between MP 215 and MP 340, the scale for rating the motorcycle related crash emphasis area is:

- Above average frequency: > 10% for rural segments and > 19 for urban segments
- Average frequency: 5%-10% for rural segments and 9%-19% for urban segments
- Below average frequency: < 5% for rural segments and < 9% for urban segments

Crash Frequency Hot Spots
A "hot spot" analysis identifies abnormally high concentrations of fatal and incapacitating injury crashes along the study corridor by direction of travel. The location of crash concentrations involves a GIS-based function known as "kernel density analysis".

2.6. Freight Performance Area

The Freight Performance Area consists of a primary measure (Freight Index) and four secondary measures as illustrated in Figure 9. All measures relate to the reliability of truck travel as measured by observed truck travel speeds and delays to truck travel from freeway closures or physical restrictions to truck travel. The results of the Freight Performance Area for I-17 are presented in Chapter 3. A detailed methodology for calculating the performance measures is provided in the Appendix.

Figure 9 - Freight Performance Area Measures

2.6.1 Primary Measure

The Freight Index is a reliability performance measure based on the planning time index for truck travel. The industry standard definition for the Truck Planning Time Index (TPTI) is the ratio of total travel time needed for 95 percent on-time arrival to free-flow travel time. The TPTI reflects the extra buffer time needed for on-time delivery while accounting for non-recurring delay. Non-recurring delay refers to unexpected or abnormal delay due to closures or restrictions resulting from circumstances such as crashes, inclement weather, and construction activities.

The TPTI was converted into a speed-based index by recognizing that speed is equal to distance traveled divided by travel time. The inverse relationship between travel time and speed means that the 95th percentile highest travel time corresponds to the 5th percentile lowest speed.

The speed-based TPTI is calculated using the following formula:

TPTI = Free-Flow Truck Speed / Observed 5th Percentile Lowest Truck Speed

Observed 5th percentile lowest truck speeds are available in the 2013 American Digital Cartography, Inc. HERE (formerly NAVTEQ) database to which ADOT has access. The free-flow truck speed is assumed to be 65 miles per hour (mph) or the posted speed, whichever is less. This upper limit of 65 mph accounts for governors that trucks often have that restrict truck speeds to no more than 65 mph, even when the speed limit may be higher.

For each corridor segment, the TPTI is calculated for each direction of travel and then averaged to create a bi-directional TPTI. When assessing performance using TPTI, the higher the TPTI value is above 1.0, the more buffer time is needed to ensure on-time delivery.

The Freight Index can be calculated using the following formula to invert the overall TPTI:

Freight Index = 1 / Bi-directional TPTI

This inversion of the TPTI allows the Freight Index to have a scale where the higher the value, the better the performance, which is similar to the directionality of the scales of the other Primary Measures. This Freight Index scale is based on inverted versions of TPTI scales created previously by ADOT. The scale for rating the Freight Index is:

- Good: > 0.77
- Fair: 0.67-0.77
- Poor: < 0.67

2.6.2 Secondary Measures

Four secondary measures will be evaluated:

- Non-Recurring Delay
- Recurring Delay
- Road Closures
- Truck Restriction Hot Spots

Non-Recurring Delay (Directional TPTI)

The performance measure for non-recurring delay is the Directional TPTI. Directional TPTI is calculated as previously described as an interim step in the development of the Freight Index.

For each corridor segment, the TPTI is calculated for each direction of travel. With the TPTI, the higher the TPTI value is above 1.0, the more buffer time is needed to ensure on-time delivery.

The scale for rating the Directional TPTI is the inverse of the Freight Index:

- Good: < 1.3
- Fair: 1.3-1.5
- Poor: > 1.5

Recurring Delay (Directional TTTI)

The performance measure for recurring delay is the Directional Truck Travel Time Index (TTTI). The industry standard definition for TTTI is the ratio of average peak period travel time to free-flow travel time. The TTTI reflects the extra time spent in traffic during peak times due to recurring delay. Recurring delay refers to expected or normal delay due to roadway capacity constraints or traffic control devices.

Similar to the TPTI, the TTTI can be converted into a speed-based index by recognizing that speed is equal to distance traveled divided by travel time. The speed-based TTTI can be calculated using the following formula:

TTTI = Free-Flow Truck Speed / Observed Average Peak Period Truck Speed

Observed average peak period truck speeds are available in the 2013 American Digital Cartography, Inc. HERE (formerly NAVTEQ) database to which ADOT has access. The free-flow truck speed is assumed to be 65 mph or the posted speed, whichever is less.

For each corridor segment, the TTTI is calculated for each direction of travel. With the TTTI, the higher the TTTI value is above 1.0, the more time is spent in traffic during peak times. TTTI values are generally lower than TPTI values.

The scale for rating the Directional TTTI is:

- Good: < 1.15
- Fair: 1.15-1.33
- Poor: > 1.15

Road Closures (Closure Duration)

The performance measure related to road closures is average roadway closure (i.e., full lane closure) duration time. There are three main components to full closures that affect reliability – frequency, duration, and extent. In the freight industry, closure duration is the most important component because trucks want to minimize travel time and delay.

Data on the frequency, duration, and extent of full roadway closures on the ADOT State Highway System is available for 2009-2013 in the Highway Condition Reporting System (HCRS) database that is managed and updated by ADOT.

The average closure duration in a segment in terms of the average time a milepost is closed per mile per year on a given segment is calculated using the following formula:

Closure Duration = Sum of Segment (Closure Clearance Time * Closure Extent) / Segment Length

The segment closure duration time in hours can then be compared to statewide averages for the nine strategic corridors closure, with one standard deviation from the average forming the scale break points. The scale for rating closure duration in hours is:

- Good: < 0.81 (48 minutes)
- Fair: 0.81-18.55
- Poor: > 18.55 (18 hours, 32 minutes)

Truck Restriction Hot Spots (Vertical Clearance)

The performance measure related to truck restrictions is the number of locations, or "hot spots", where vertical clearance issues restrict truck travel. Sixteen feet is the minimum standard vertical clearance value for interstate bridges.

Locations with lower vertical clearance values than the minimum standard are categorized by the ADOT Intermodal Transportation Department Engineering Permits Section as either a location where ramps exist that allow the restriction to be avoided, or a location where ramps do not exist and the restriction cannot be avoided. The locations with vertical clearances below the minimum standard will be mapped to identify their geographic location and whether or not the restricted area can be avoided.

3. CORRIDOR HEALTH

3.1. Pavement Performance

The Pavement Index and secondary performance measures were calculated for the I-17 corridor as described in Section 2.2. The pavement measures were calculated using pavement condition data provided by ADOT for the timeframe from 2013 and 2014.The Pavement Index provides a top-level assessment of the pavement condition for the corridor and for each segment. The Directional PSR and the Pavement Failure measures provide more detailed information to assess the pavement condition for each segment. The resulting scores are shown in Table 2.

Table 2 – Pavement Summary

Segment	Segment Length (miles)	Pavement Index	Directional PSR		% Pavement Failure
			NB	SB	
17-1	7	4.19	4.24	4.14	0.0%
17-2	10	4.16	4.13	4.15	0.0%
17-3	13	3.85	3.92	3.86	3.8%
17-4	8	4.25	3.65	4.25	0.0%
17-5	10	4.25	4.09	4.02	0.0%
17-6	16	4.26	4.08	4.02	0.0%
17-7	9	3.92	3.78	3.93	16.7%
17-8	11	4.32	4.01	4.17	4.5%
17-9	8	4.21	3.77	4.18	18.8%
17-10	9	4.19	4.01	4.06	0.0%
17-11	7	3.73	3.50	3.82	21.4%
17-12	17	3.70	3.49	3.82	25.7%
Weighted Average		4.07			

The results for the Pavement Index and the secondary measures are shown in Figures 10 through 12.

Based on the results of this analysis, the following observations could be made:

- Overall, based on the weighted average of the Pavement Index, the pavement is in "good" condition
- There are several failure hot spots along the corridor in segments 3, 7, 8, 9, 11, and 12, including 17 miles on northbound I-17 and 3 miles on southbound I-17
- Segments 11 and 12 are the only two segments on the corridor that have a "fair" pavement rating
- More than 20% of the pavement in segments 11 and 12 is in "poor" condition
- The northbound pavement is in worse condition than the southbound pavement
- Segments 11 and 12 have the lowest Pavement Index, the lowest PSR, and the highest percentage of pavement in "poor" condition

According to representatives of the Flagstaff District, the northbound pavement is in worse condition than the southbound pavement because trucks are typically loaded when driving northbound and typically unloaded when driving southbound.

Figure 10 – Pavement Index

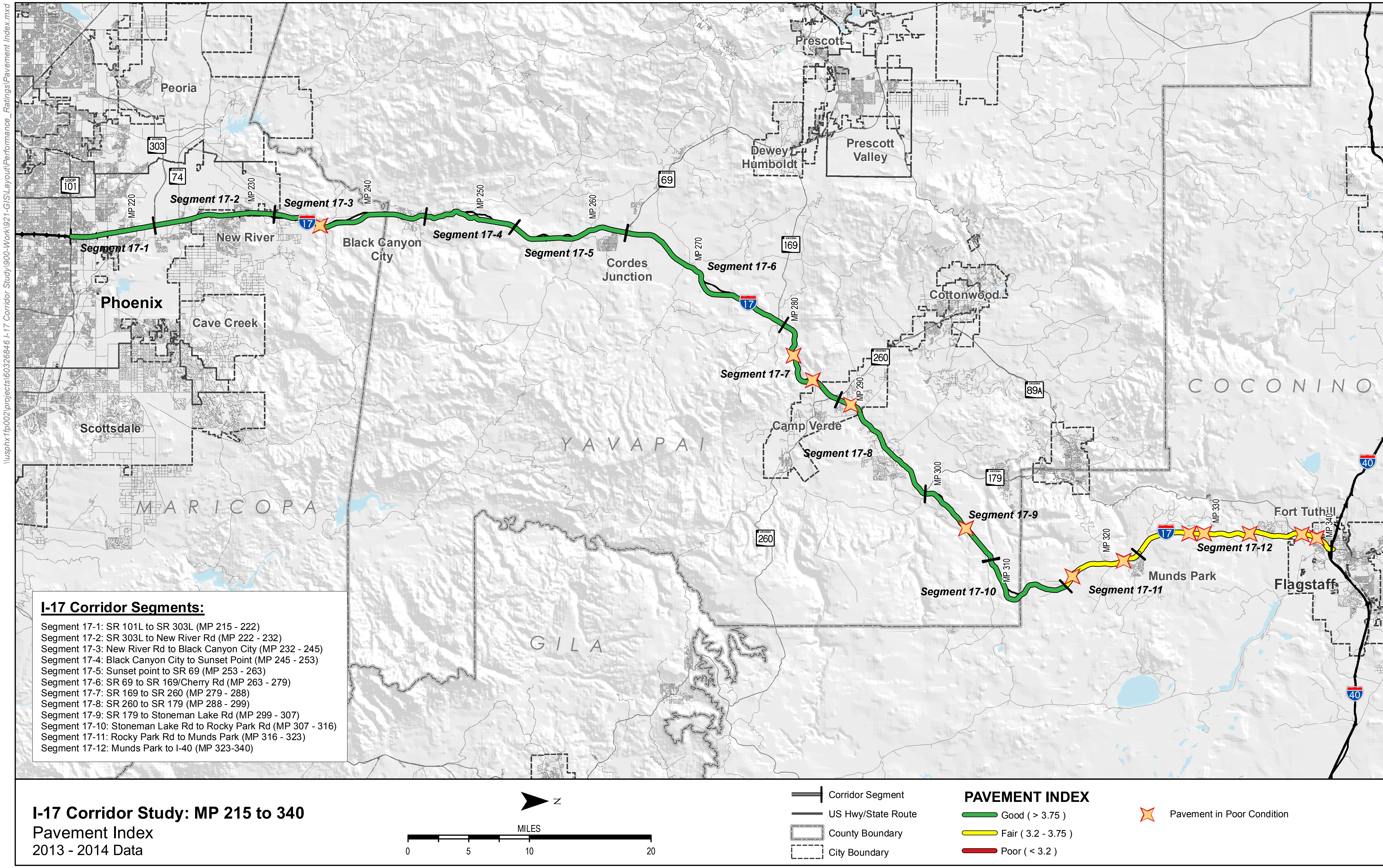


Figure 11 – Directional PSR

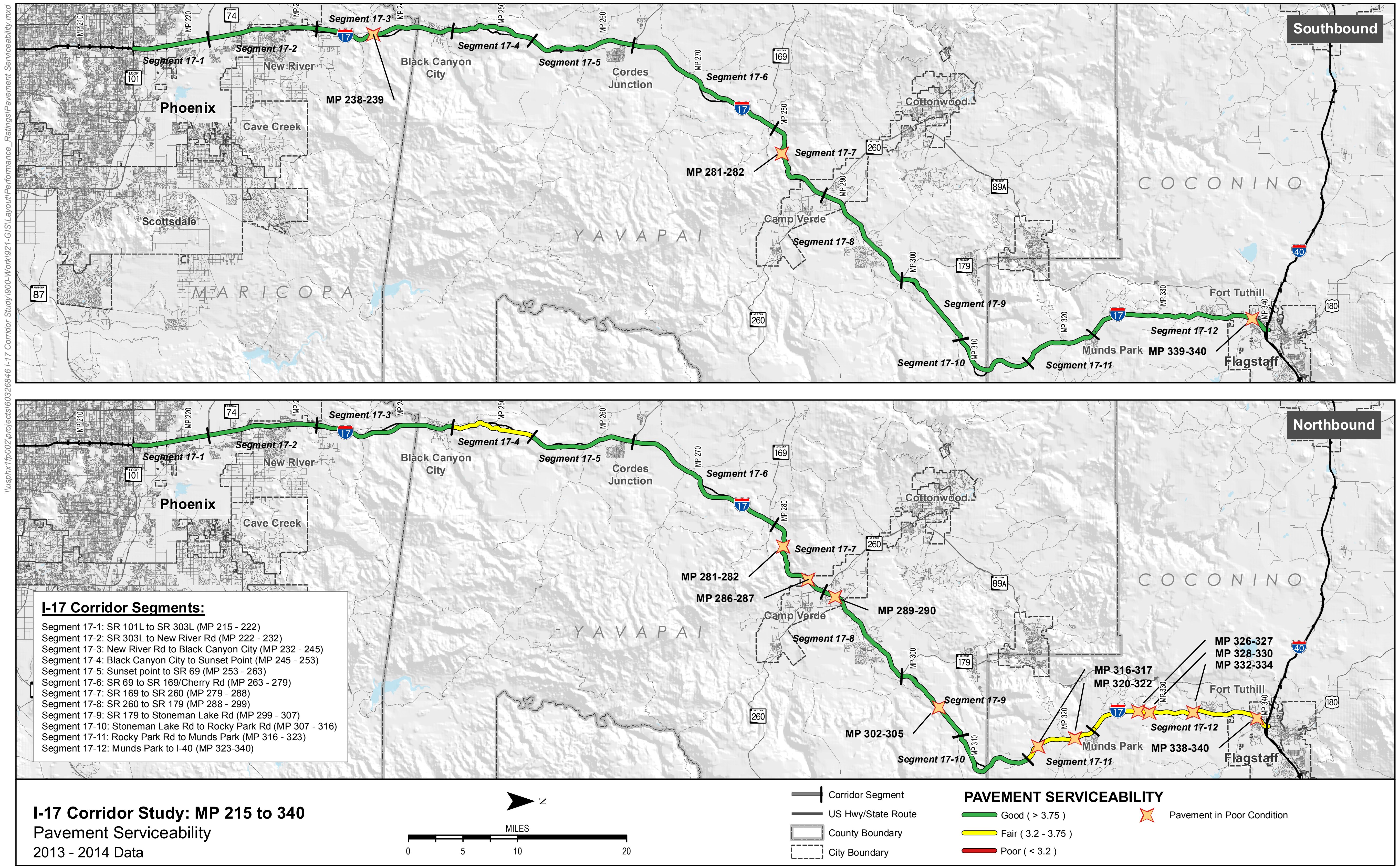
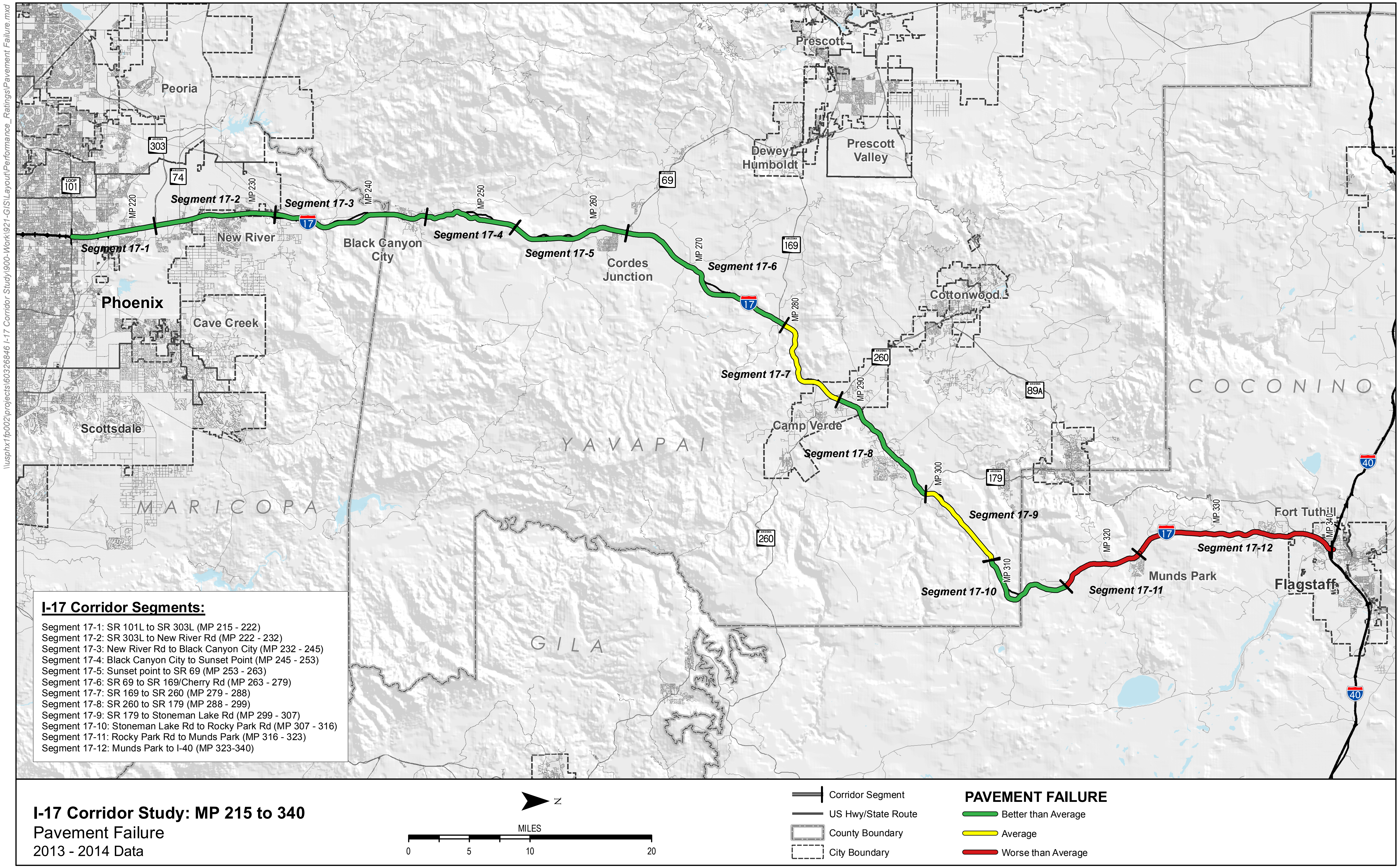


Figure 12 – Pavement Failure



3.2 Bridge Performance

The Bridge Index and secondary performance measures were calculated for the I-17 corridor as described in Section 2.3. The bridge measures were calculated using bridge condition data provided by ADOT for the timeframe from 2012 to 2014. The Bridge Index provides a top-level assessment of the structural condition for the corridor and for each segment. The Sufficiency Rating and the Functionally Obsolete Bridge measures provide more detailed information to assess the bridge condition for each segment. The resulting scores are shown in Table 3.

Table 3 – Bridge Summary

Segment	Segment Length (miles)	Bridge Index	Bridge Sufficiency	% Functionally Obsolete Bridges
17-1	7	6.76	90.95	31.1%
17-2	10	6.79	92.73	14.6%
17-3	13	6.39	91.10	31.3%
17-4	8	5.71	93.97	60.9%
17-5	10	7.25	96.41	15.0%
17-6	16	6.19	94.82	8.5%
17-7	9	6.31	91.41	0.0%
17-8	11	6.04	89.20	13.6%
17-9	8	6.00	93.00	100.0%
17-10	9	6.52	94.00	100.0%
17-11	7	6.91	96.48	3.4%
17-12	17	5.80	92.00	62.3%
Weighted Average		6.34		

The results for the Bridge Index and secondary measures are shown in Figures 13 through 15.

Based on the results of this analysis, the following observations could be made:

- Overall, based on the weighted average of the Bridge Index, the bridges are in “fair” condition
- Nearly all of the bridges are in “good” or “fair” condition
- There is one structurally deficient bridge on the corridor, the McGuireville TI bridge located in segment 8
- There is one bridge with a sufficiency rating of “poor”, the McGuireville TI bridge located in segment 8
- There are a high number of functionally obsolete bridges in segments 1, 3, 4, 9, 10, and 12
- Segments 4 and 12 have the lowest Bridge Index and a high percentage of functionally obsolete bridges

Figure 13 – Bridge Index

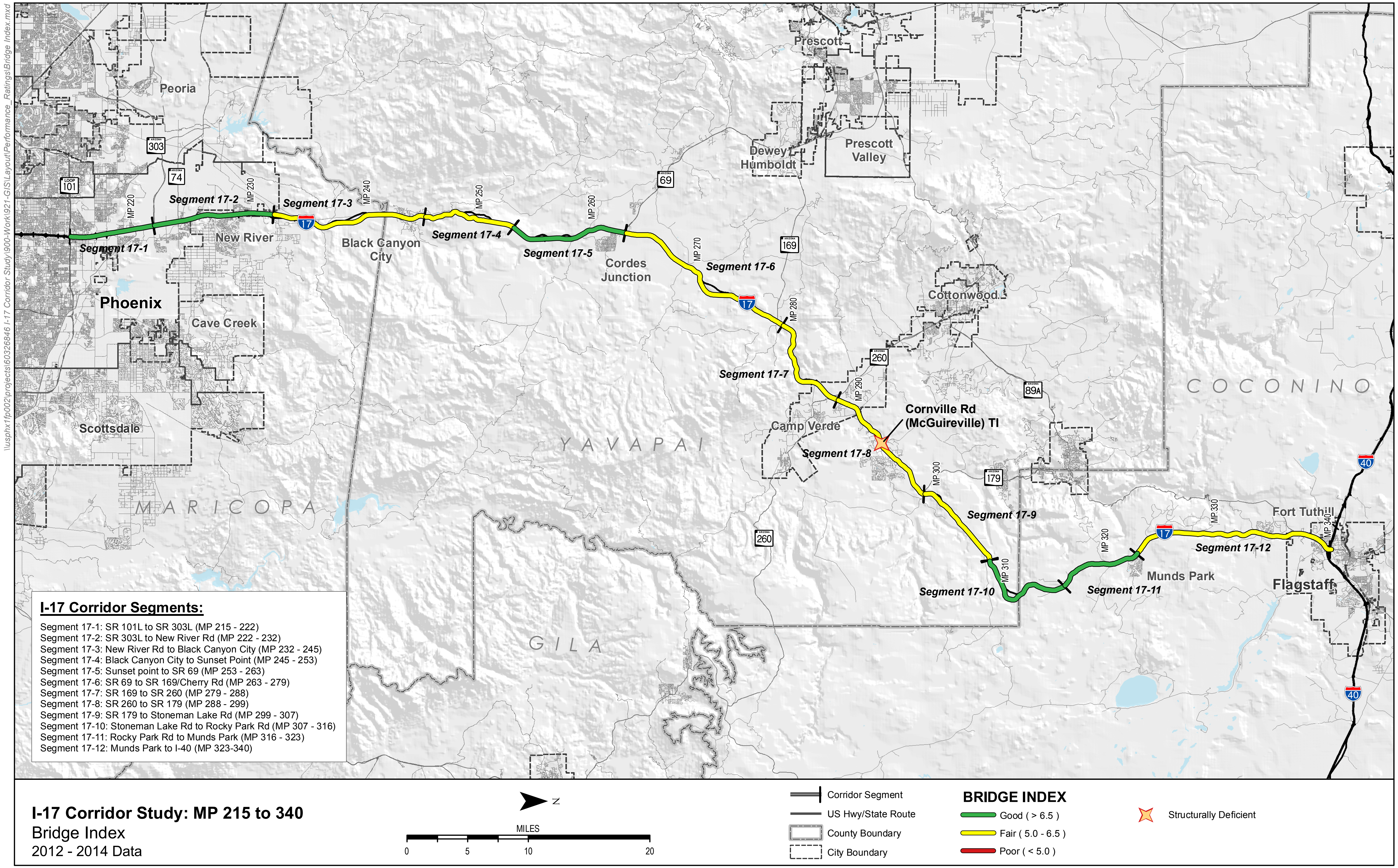


Figure 14 – Bridge Sufficiency

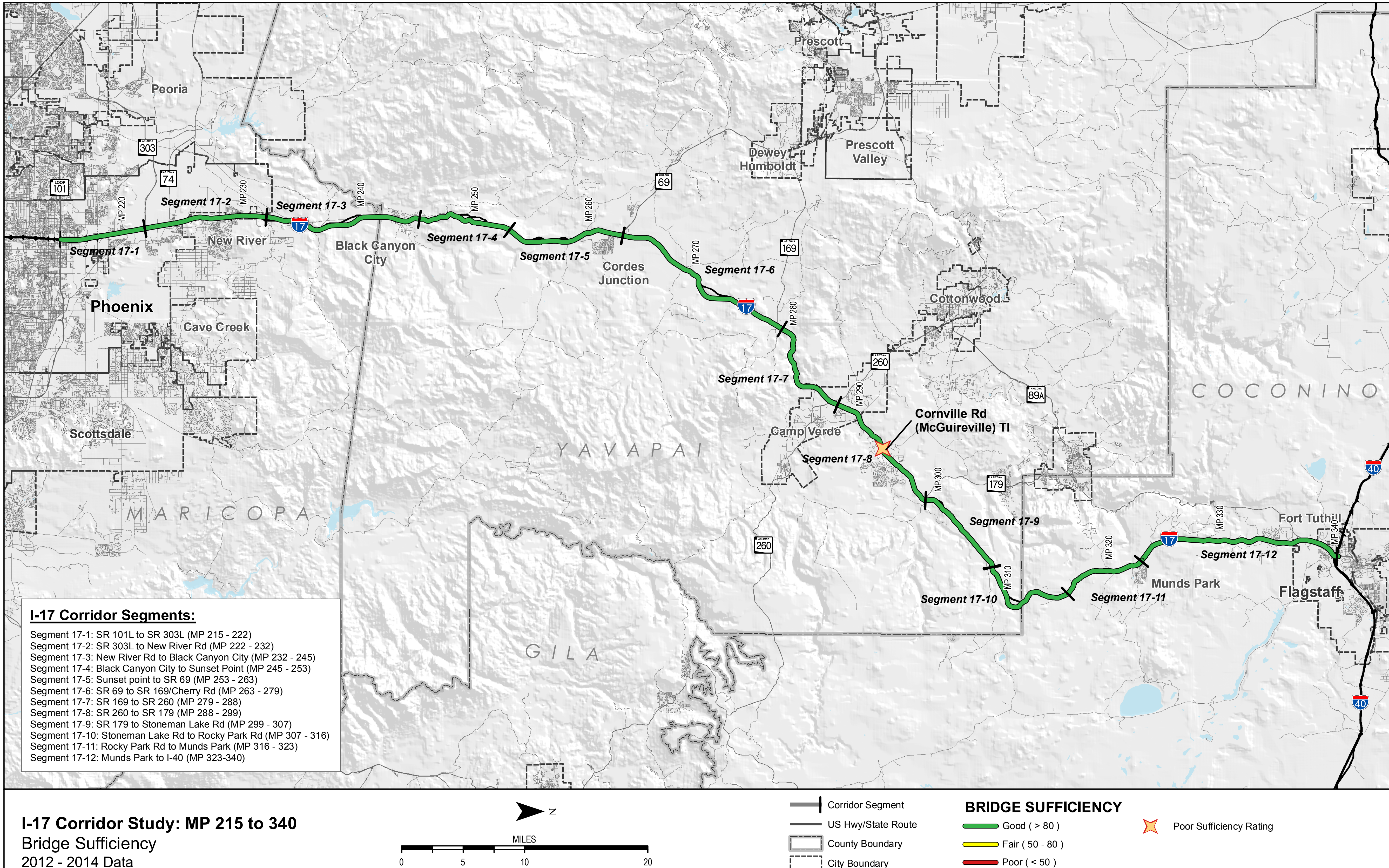
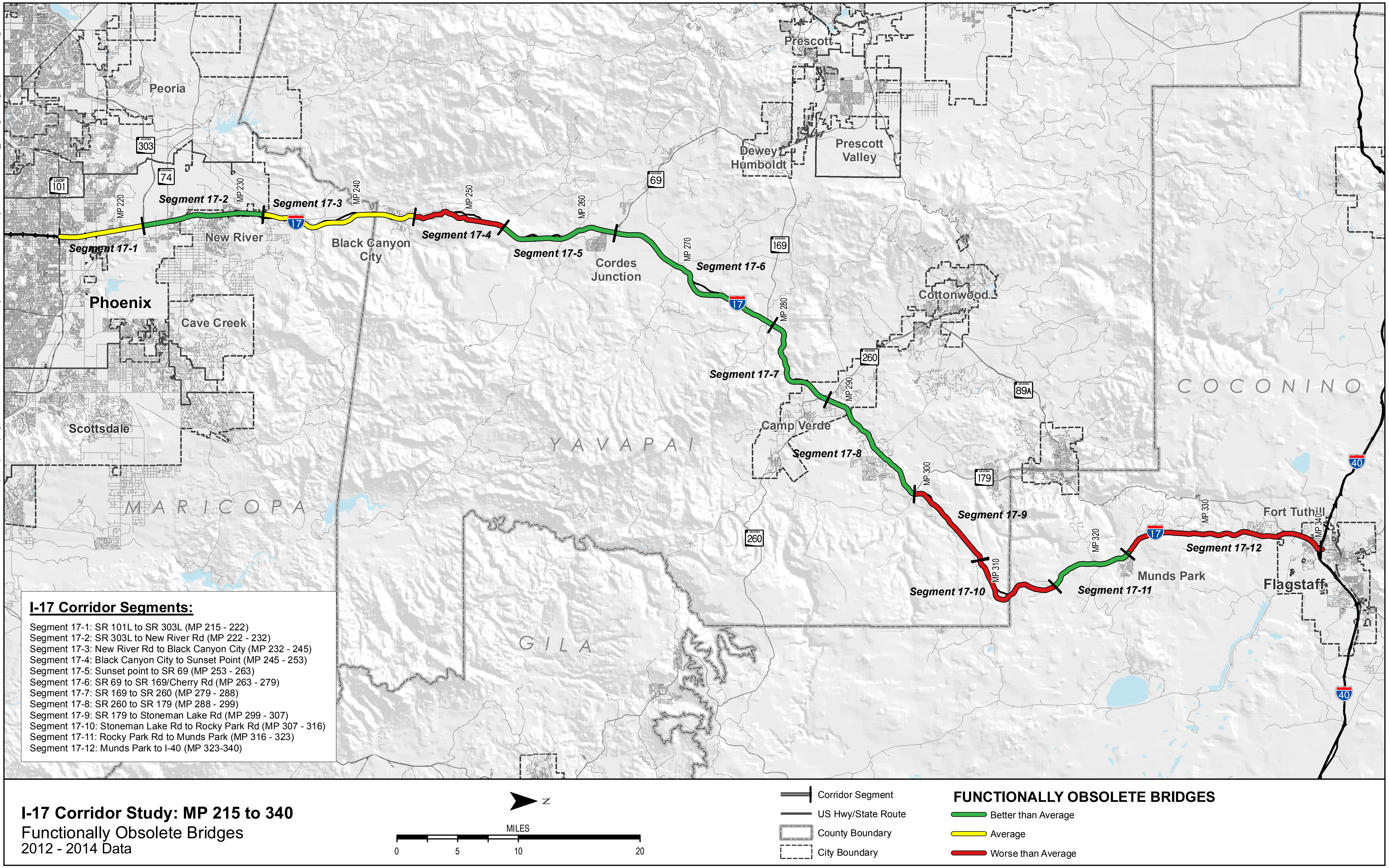


Figure 15 – Functionally Obsolete Bridges



3.3. Mobility Performance

The Mobility Index and secondary performance measures were calculated for the I-17 corridor as described in Section 2.4. The calculations were based on data provided by ADOT from the HPMS system for the year 2013, the AZTDM for the years 2010 and 2035, HERE data from 2013, and closure data from 2009 to 2013. The Mobility Index provides a top-level assessment of the traffic operational condition for the corridor and for each segment. The Future V/C, Peak Hour V/C, Closure, TTI, and PTI measures provide more detailed information to assess the traffic operational conditions for each segment. The resulting scores are shown in Table 4.

Table 4 – Mobility Summary

Segment	Segment Length (miles)	Mobility Index	Future Daily V/C	Existing Peak Hour V/C		Closure Extent (occurrences /year/mile)		Directional TTI (all vehicles)		Directional PTI (all vehicles)		% Non-SOV Trips
				NB	SB	NB	SB	NB	SB	NB	SB	
17-1	7	0.75	0.91	0.65	0.62	0.95	0.85	1.00	1.00	1.03	1.03	10.7%
17-2	10	0.57	0.67	0.57	0.55	0.37	0.50	1.07	1.04	1.15	1.11	12.3%
17-3	13	0.85	1.04	0.56	0.54	0.37	0.25	1.09	1.11	1.17	1.20	12.0%
17-4	8	0.87	1.07	0.50	0.55	0.70	1.13	1.21	1.00	1.61	1.07	12.3%
17-5	10	0.86	1.06	0.58	0.57	1.00	1.05	1.20	1.14	1.34	1.21	15.5%
17-6	16	0.51	0.63	0.37	0.36	0.41	0.53	1.13	1.38	1.23	1.69	7.7%
17-7	9	0.78	0.96	0.66	0.63	3.21	3.50	1.23	1.15	1.27	1.31	7.7%
17-8	11	0.53	0.63	0.42	0.43	0.31	0.24	1.14	1.13	1.27	1.24	14.1%
17-9	8	0.53	0.63	0.30	0.36	2.18	1.55	1.30	1.12	1.61	1.22	6.6%
17-10	9	0.43	0.51	0.25	0.28	2.19	1.55	1.29	1.13	1.60	1.25	6.3%
17-11	7	0.36	0.43	0.23	0.26	1.89	1.60	1.10	1.08	1.18	1.16	6.2%
17-12	17	0.36	0.44	0.23	0.28	1.68	1.37	1.05	1.04	1.13	1.11	17.9%
Weighted Average		0.60										

The results for the Mobility Index and secondary measures are shown in Figures 16 through 21. The results of the multimodal opportunities secondary measure are shown in Figure 22.

Based on the results of this analysis, the following observations could be made:

- Overall, based on the weighted average of the Mobility Index, the traffic operations are in “fair” condition
- The existing peak hour traffic operations are generally “good” with only two segments showing “fair” performance
- The future traffic operations are anticipated to perform “poor” in five of the twelve segments
- Segments 3, 4, 5, and 7 have the lowest Mobility Index and perform the worst in the Future V/C performance measure
- A majority of the segments show either “fair” or “poor” performance in the Closure performance measure
- Segments 7, 9, 10, 11, and 12 have the highest number of closures
- The TTI and PTI measures generally show “fair” or “poor” performance in the uphill direction of travel in mountainous areas
- Segments 4, 6, 9, and 10 appear to have least reliable travel time as they have the greatest difference between the TTI and PTI
- A majority of the corridor shows “poor” or “fair” performance for non-SOV trips meaning that many vehicles carry only a single occupant
- Every segment shows “poor” performance in at least one performance measure except segments 2 and 8

ADOT"s Traffic Data Monitoring System (TDMS) includes a series of permanent traffic count stations that report daily traffic volumes 365 days per year. ADOT provided count data from 2008 to 2013 for the 15 permanent count stations located on the I-17 corridor. This data was reviewed to estimate variations in traffic volumes during different days of the week.

The 15 permanent count stations are located in Segments 1, 2, 6, 7, 8, and 11. At each permanent count station, the daily traffic volume data was reviewed for one week during each season (winter, spring, summer, and fall) to estimate the average annual variation in daily traffic volumes for mid-week (Tuesday, Wednesday, Thursday) volumes compared to Friday and weekend (Saturday and Sunday) volumes. Based on this data, the following observations were made:

- Segment 1 currently experiences a slight decrease in daily traffic volumes on the weekend and a slight increase (10%-15%) in daily traffic volumes on Friday when compared to mid-week. This is likely due to the urban character at the southern end of the corridor with high commuter traffic during the week.
- Segment 2 currently experiences a 5%-15% increase in daily traffic volumes on the weekend and a 20%-25% increase in daily traffic volumes on Friday when compared to mid-week.

- The middle and northern end (Segments 6, 7, 8, and 11) of the corridor currently experience a 30%-35% increase in daily traffic volumes on Friday and on the weekend when compared to mid-week.

The results shown in Table 4 and Figures 16 through 21 are based on mid-week traffic volumes. This analysis shows that the weekend daily traffic volumes can increase as much as 35% compared to the mid-week volumes. The higher traffic volumes would degrade the traffic operations and result in worse performance than shown in the data presented in Table 4 and Figures 16 through 21.

According to representatives of the ADOT Prescott District, Segment 4 currently has numerous issues with congestion, travel delays, and trip reliability. As shown above, Segment 4 performs “poor” in the Mobility Index, Future V/C, Planning Time Index, and has one of the least reliable travel times.

Figure 16 – Mobility Index

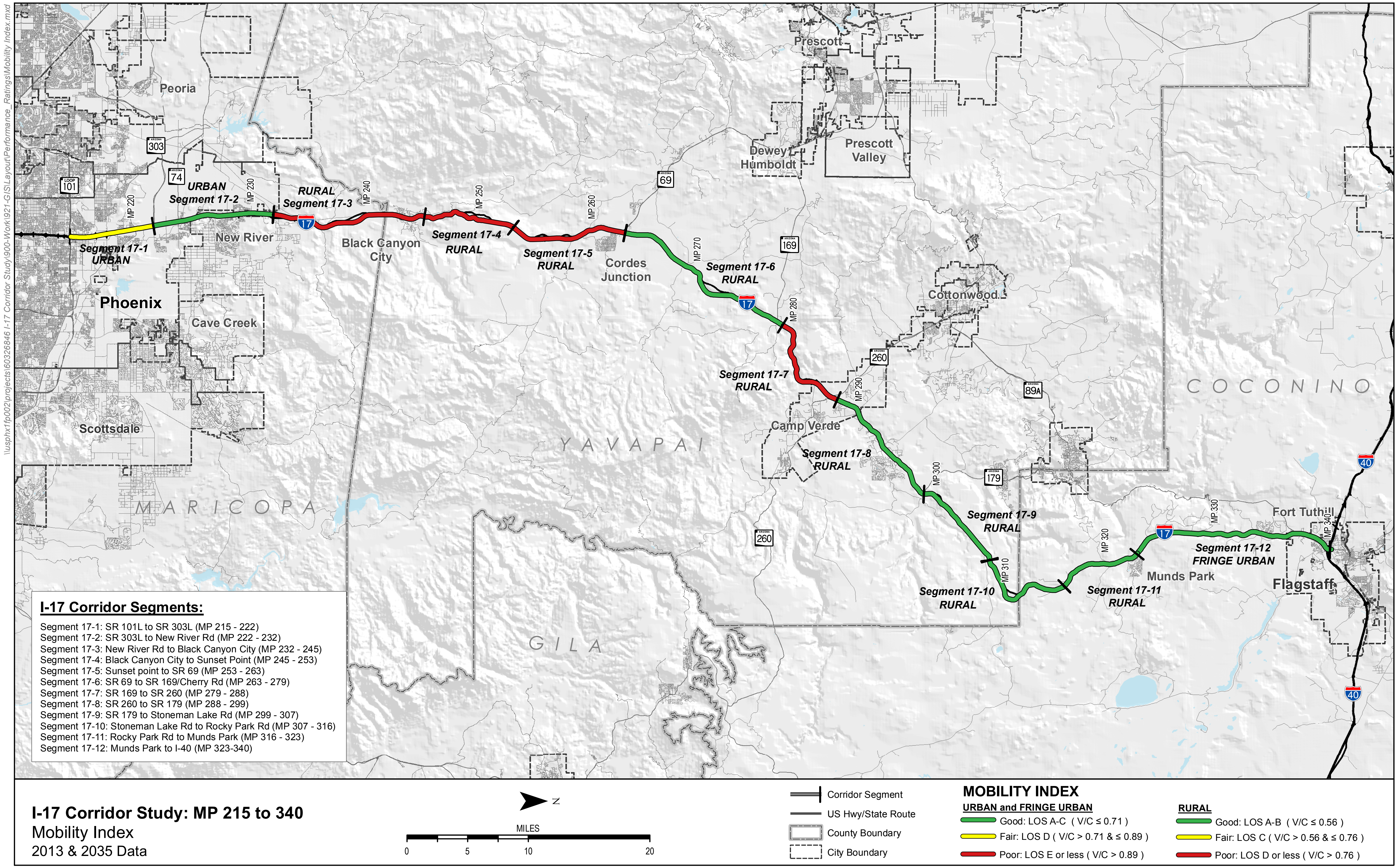


Figure 17 – Future V/C

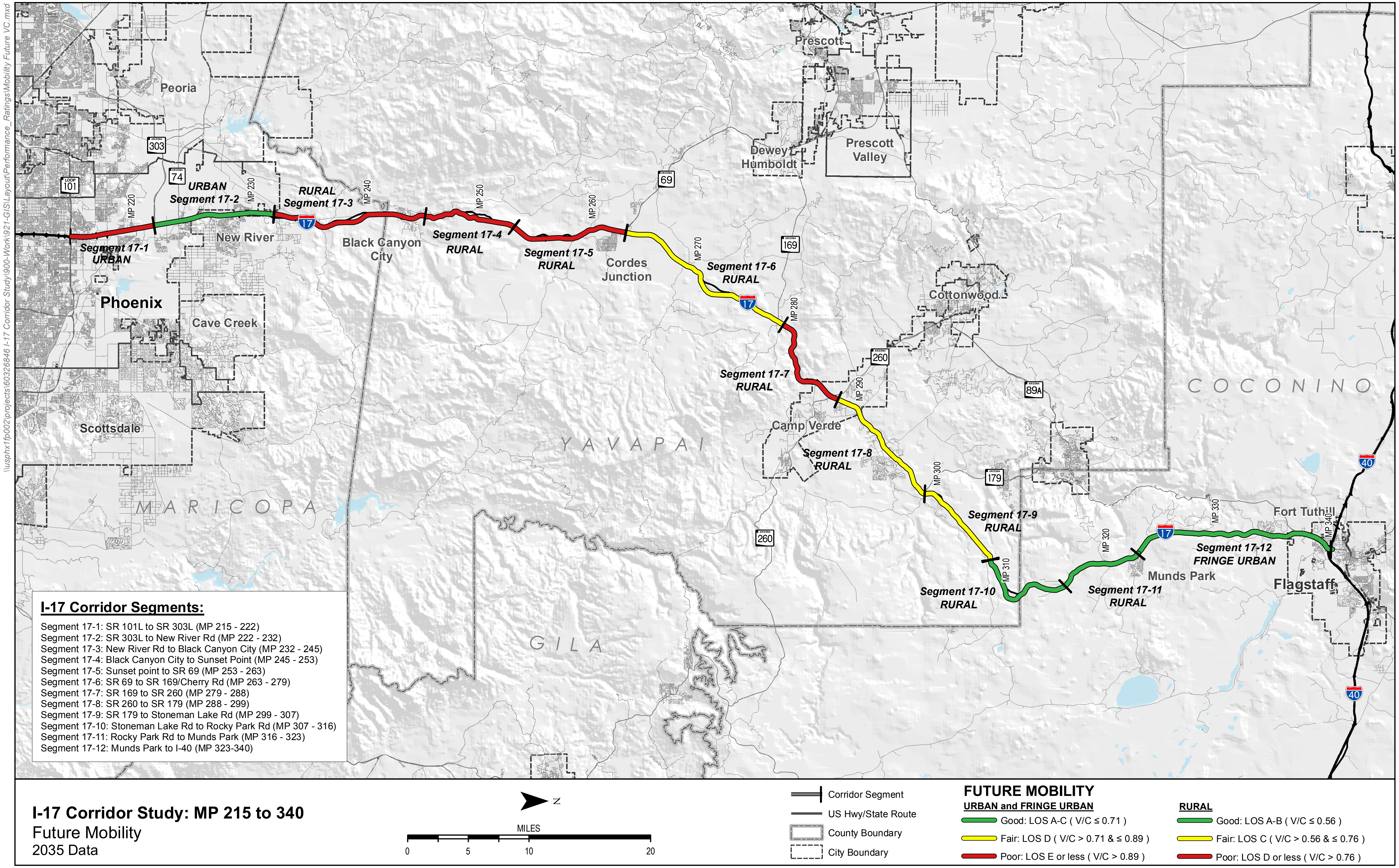


Figure 18 – Existing Peak Hour V/C

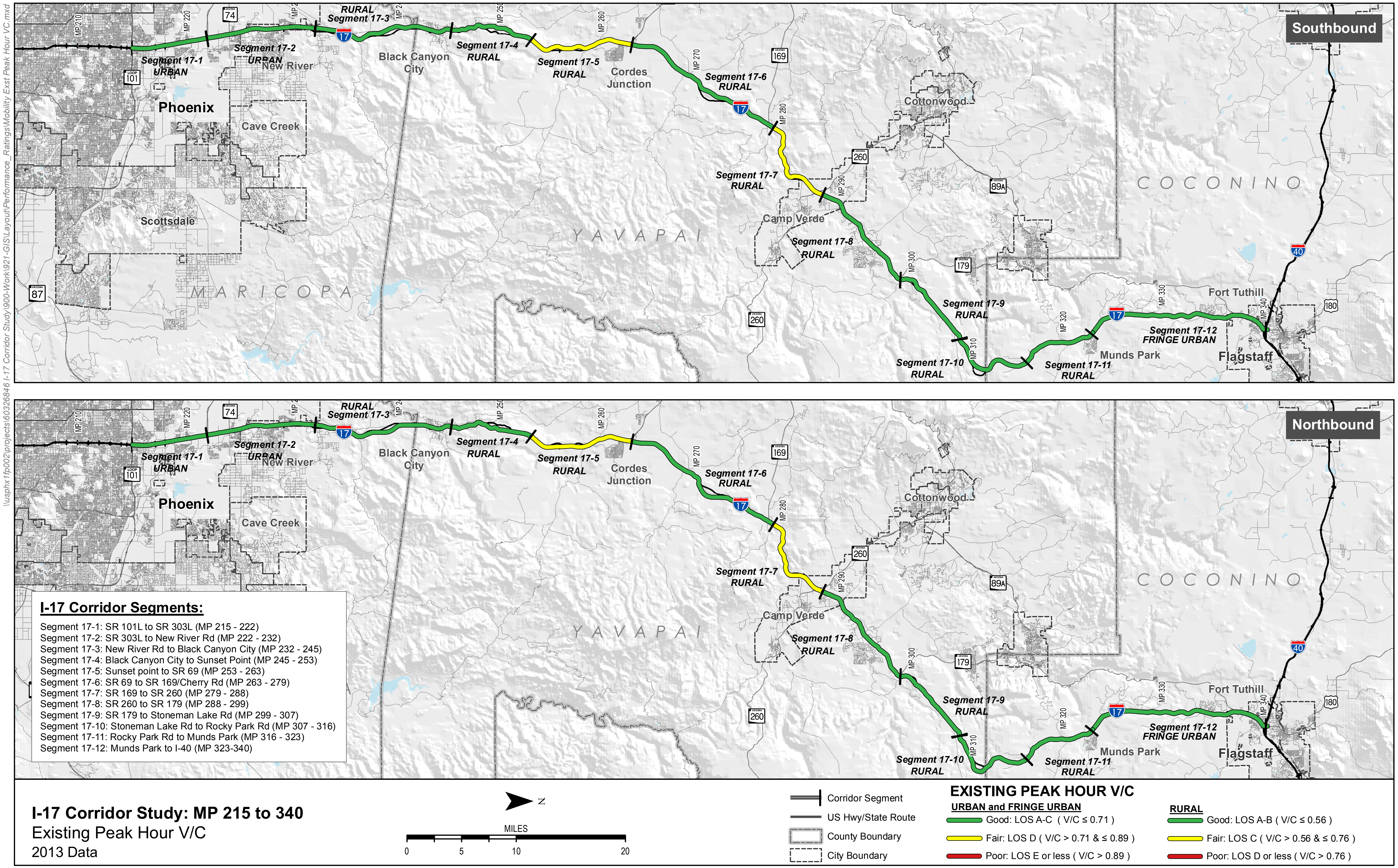


Figure 19 – Frequency of Closures

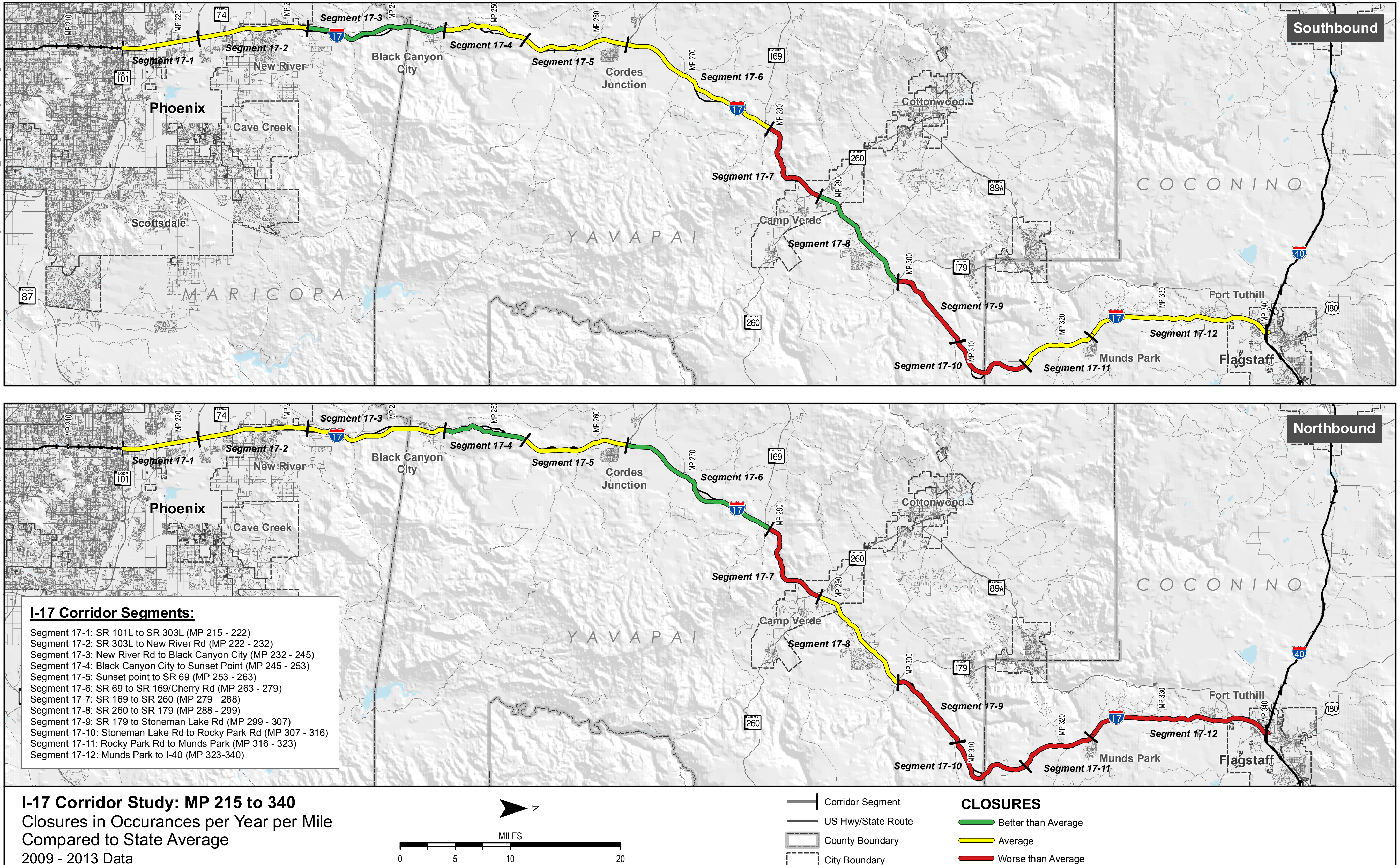


Figure 20 – Travel Time Index

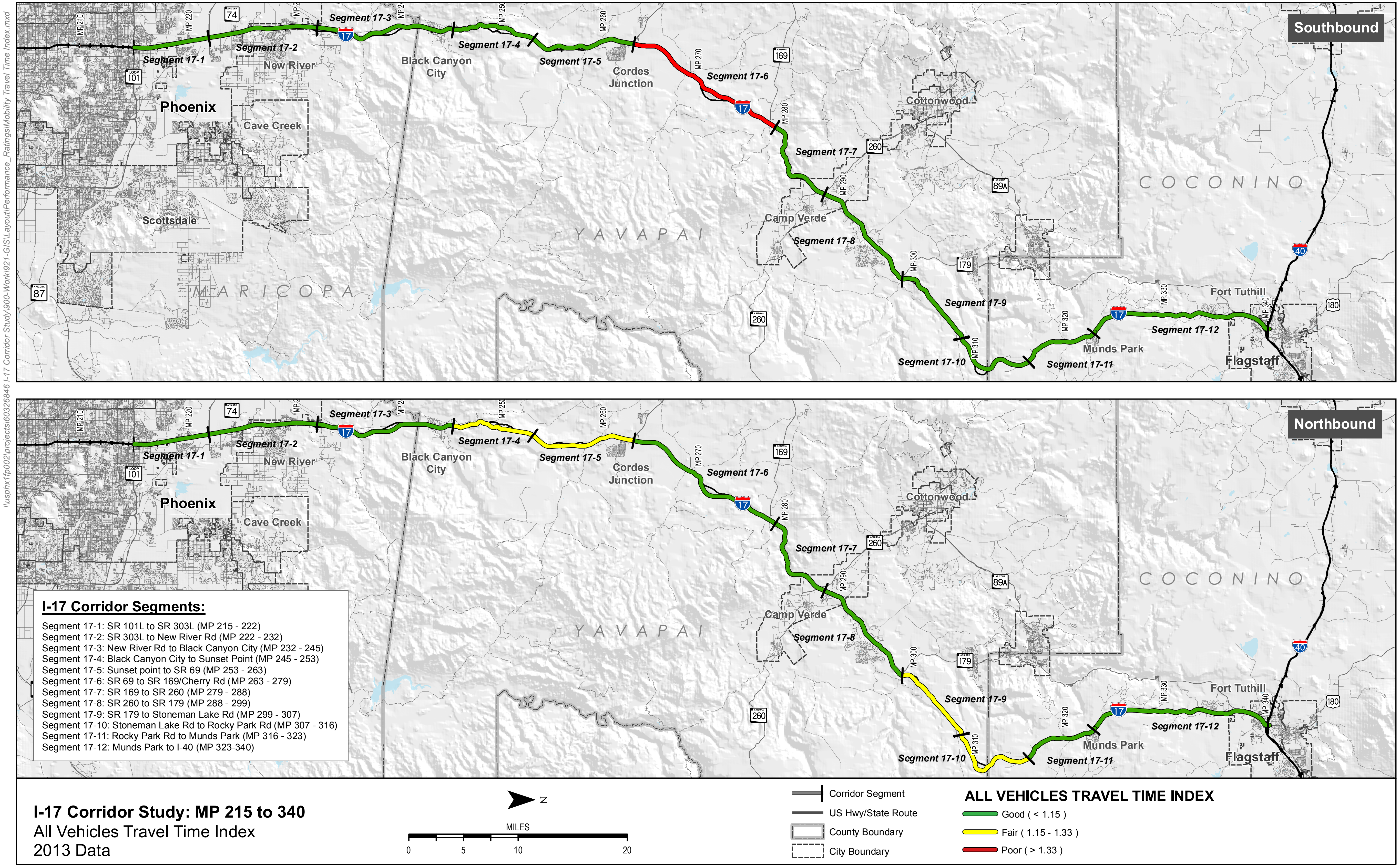


Figure 21 – Planning Time Index

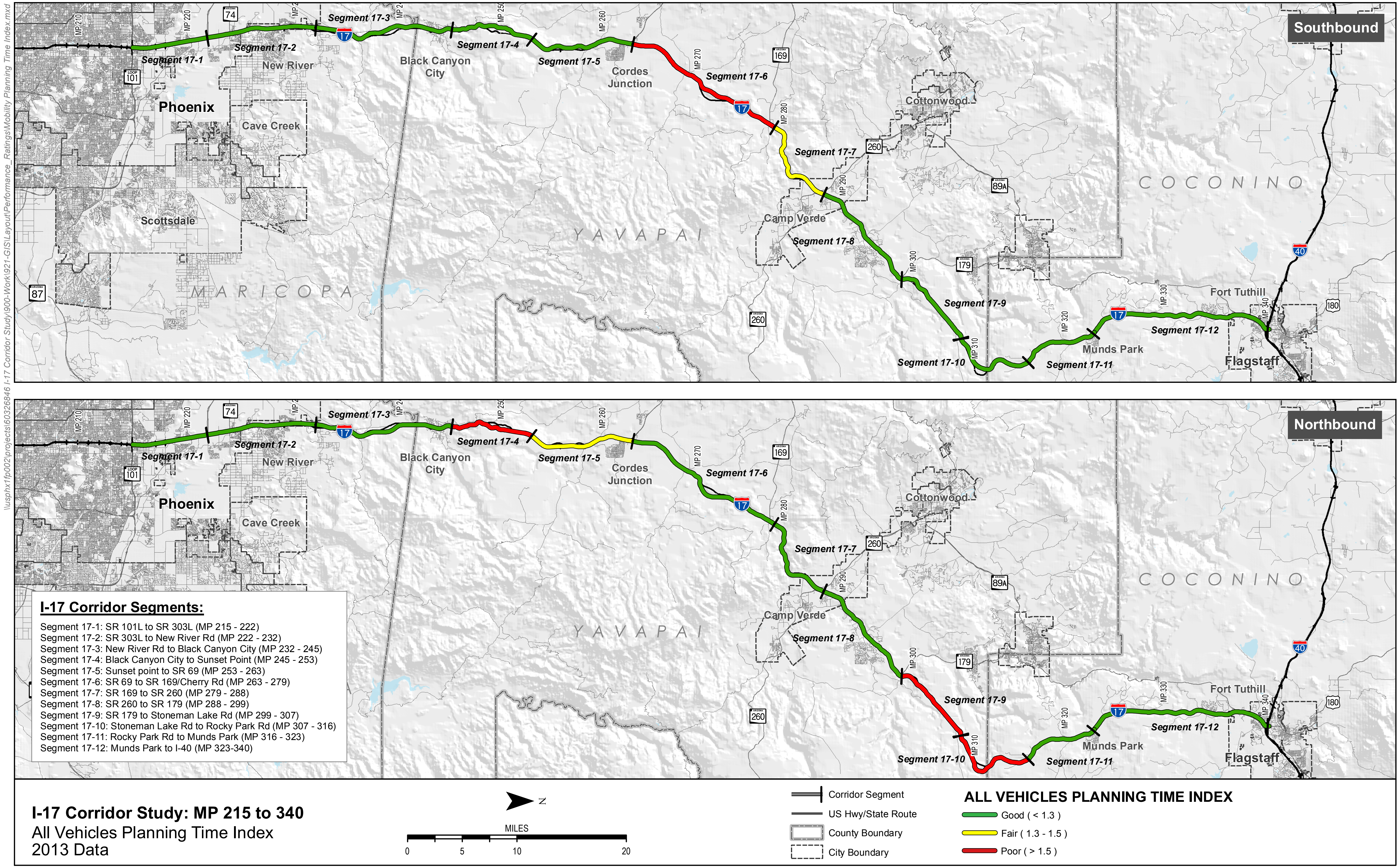
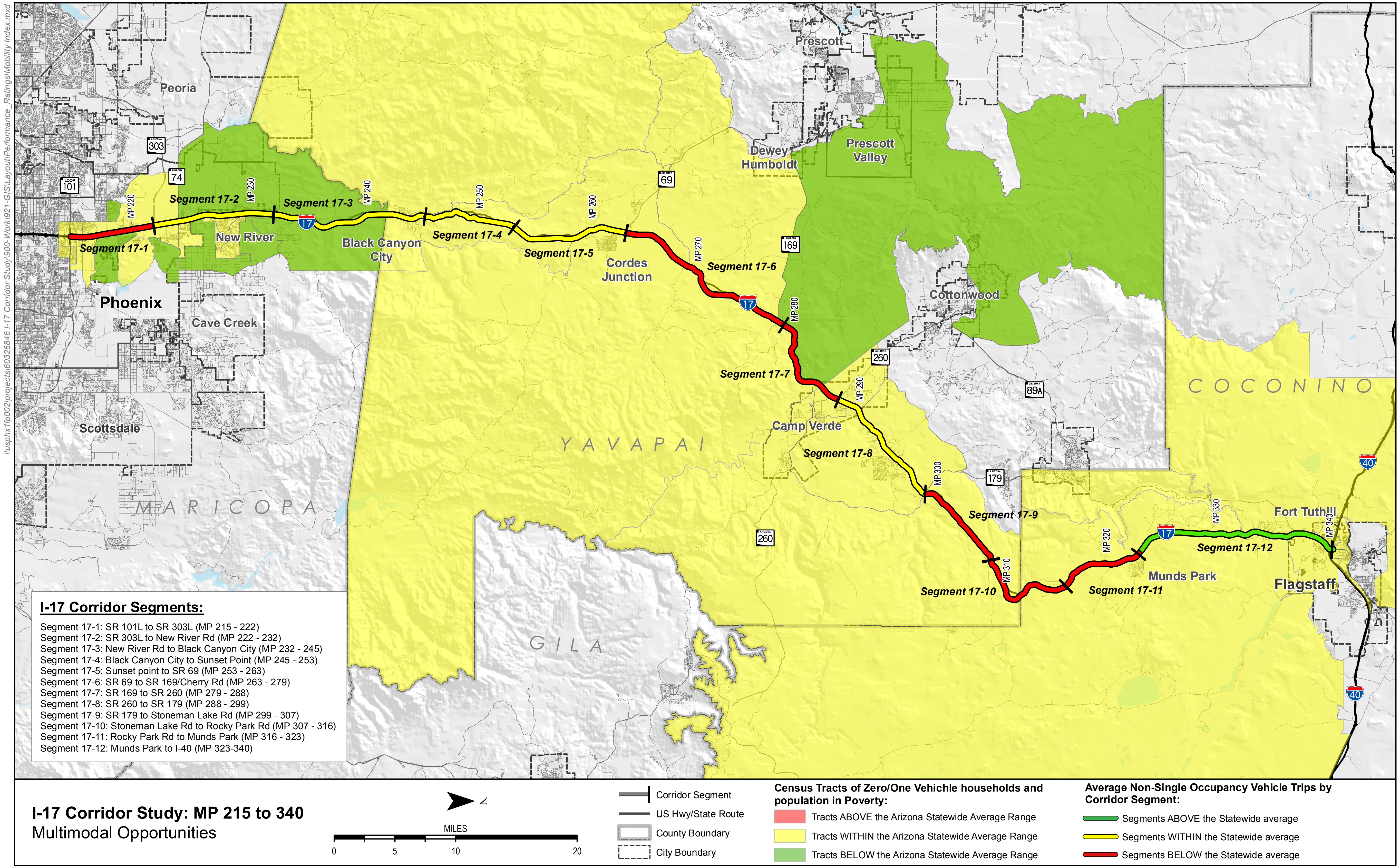


Figure 22 – Transit Dependency



3.4. Safety Performance

The Safety Index and secondary performance measures were calculated for the I-17 corridor as described in Section 2.5. The safety measures were calculated using data provided by ADOT for the timeframe from January 2009 to December 2013. The Safety Index provides a top-level assessment of the safety performance for the corridor and for each segment. The three supplemental measures provide more detailed information to assess the safety performance for each segment. The resulting scores are shown in Table 5. As discussed in Section 2.5, all analysis is based on fatal and incapacitating injury crashes.

Table 5 – Safety Summary

Segment	Segment Length (miles)	Safety Index	% of Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	% of Fatal + Incapacitating Injury Crashes Involving Trucks	% of Fatal + Incapacitating Injury Crashes Involving Motorcycles
17-1	7	0.83	0%	0%	0%
17-2	10	0.77	31%	6%	6%
17-3	13	1.20	69%	10%	14%
17-4	8	0.88	35%	6%	18%
17-5	10	0.94	35%	10%	10%
17-6	16	1.37	56%	6%	17%
17-7	9	1.10	47%	7%	13%
17-8	11	0.71	58%	21%	5%
17-9	8	0.48	48%	10%	0%
17-10	9	1.24	50%	20%	0%
17-11	7	0.87	29%	7%	7%
17-12	17	1.80	33%	4%	8%
Weighted Average		1.09			

The results for the Safety Index and secondary measures are shown in Figures 23 through 26. The results of the hot spot analysis are shown in Figure 27.

Based on the results of this analysis, the following observations could be made:

- Overall, based on the weighted average of the Safety Index, the corridor rates in "fair" condition
- A majority of the segments either perform "fair" or "poor" in the Safety Index
- Only segments 6, 10, and 12 perform "good" in the Safety Index
- Segments 8 and 9 have the lowest rating the Safety Index
- Segment 8 performs "poor" in the Safety Index, top 5 SHSP emphasis areas, and truck-involved crashes
- There are several locations of high crash frequency, including northbound in Segments 1, 2, 3, and 11, and southbound in Segments 1, 2, 3, 4, 7, 8, 9, 10, and 12

According to representatives of the ADOT Prescott District, there are high crash locations located within segment 4. Segment 4 does score "fair" or "poor" in two of the performance measures listed in Table 5. In addition, segment 4 does show one "hot spot" southbound and two "hot spots" northbound in Figure 27.

According to representatives of the ADOT Flagstaff District, the high crash locations are located near MP 312 (northbound), MP 313 (northbound and southbound), MP 317 (northbound), and MP 331 (northbound and southbound). These locations are within segments 10, 11, and 12 which all show "fair" or "poor" performance in at least one of the performance measures listed in Table 5. In addition, mileposts 312, 313, and 317 generally correspond to locations identified as "hot spots" in Figure 27.

Figure 23 – Safety Index

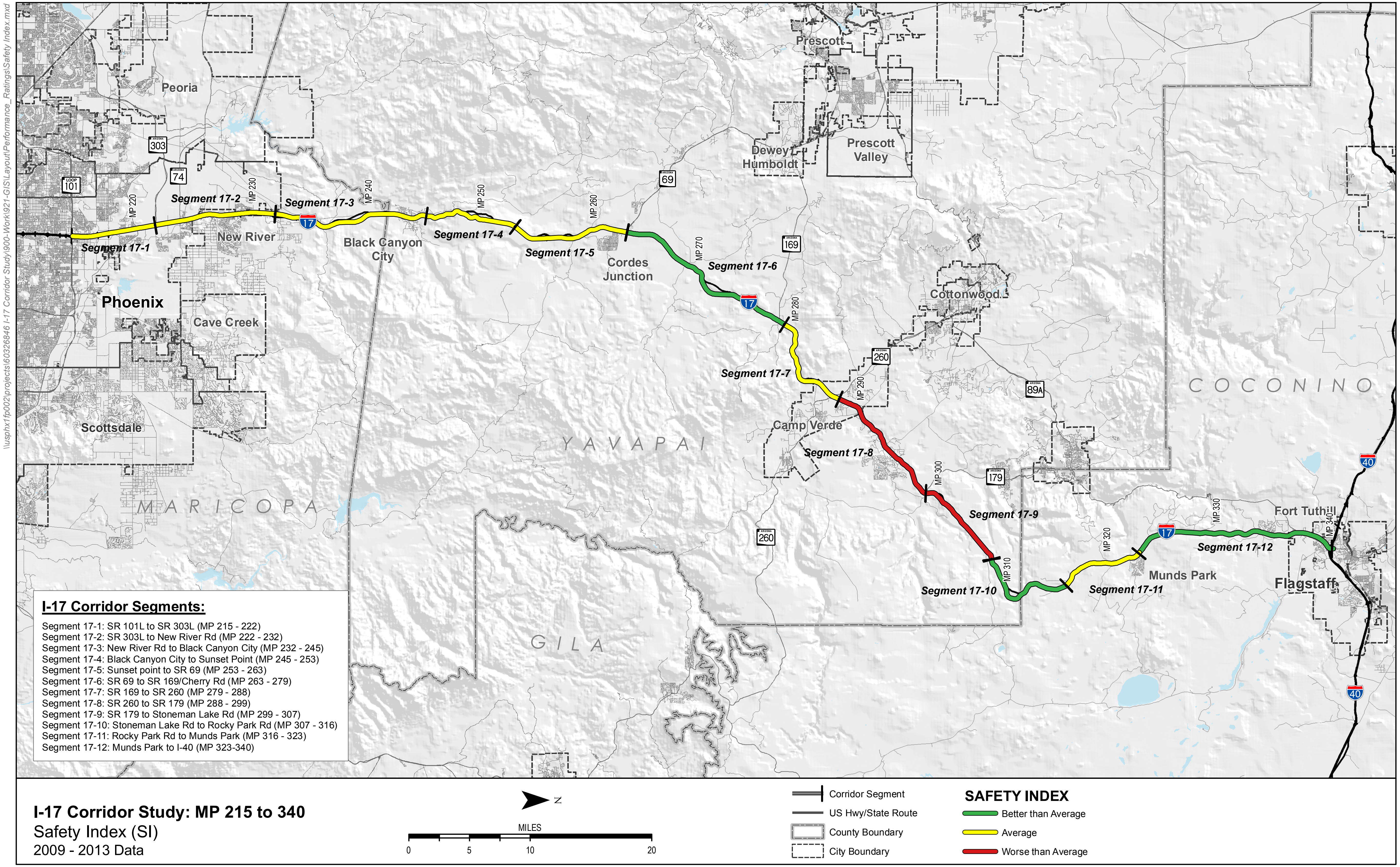


Figure 24 – Frequency of SHSP Top 5 Emphasis Areas

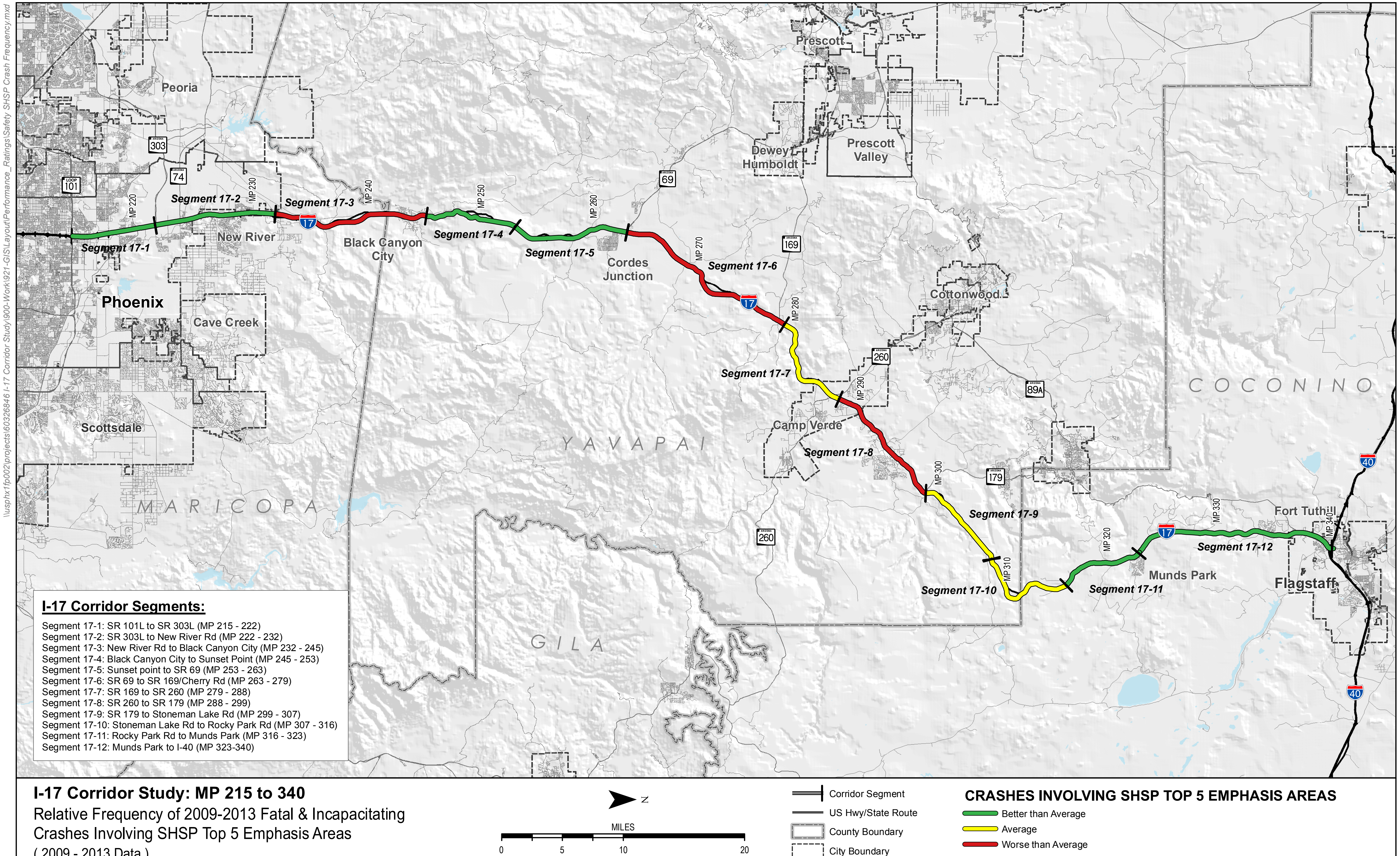


Figure 25 – Frequency of Crashes Involving Trucks

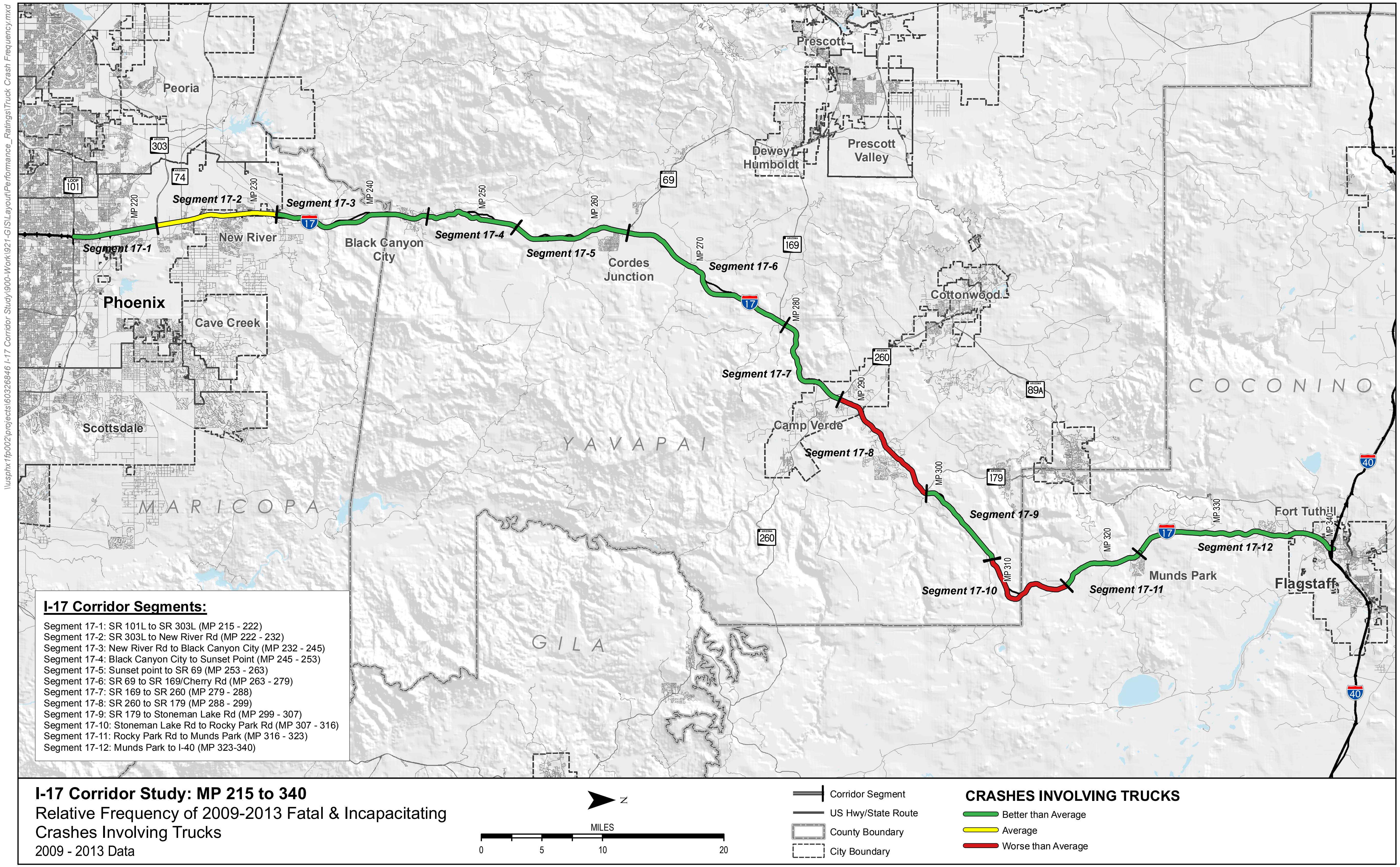


Figure 26 – Frequency of Crashes Involving Motorcycles

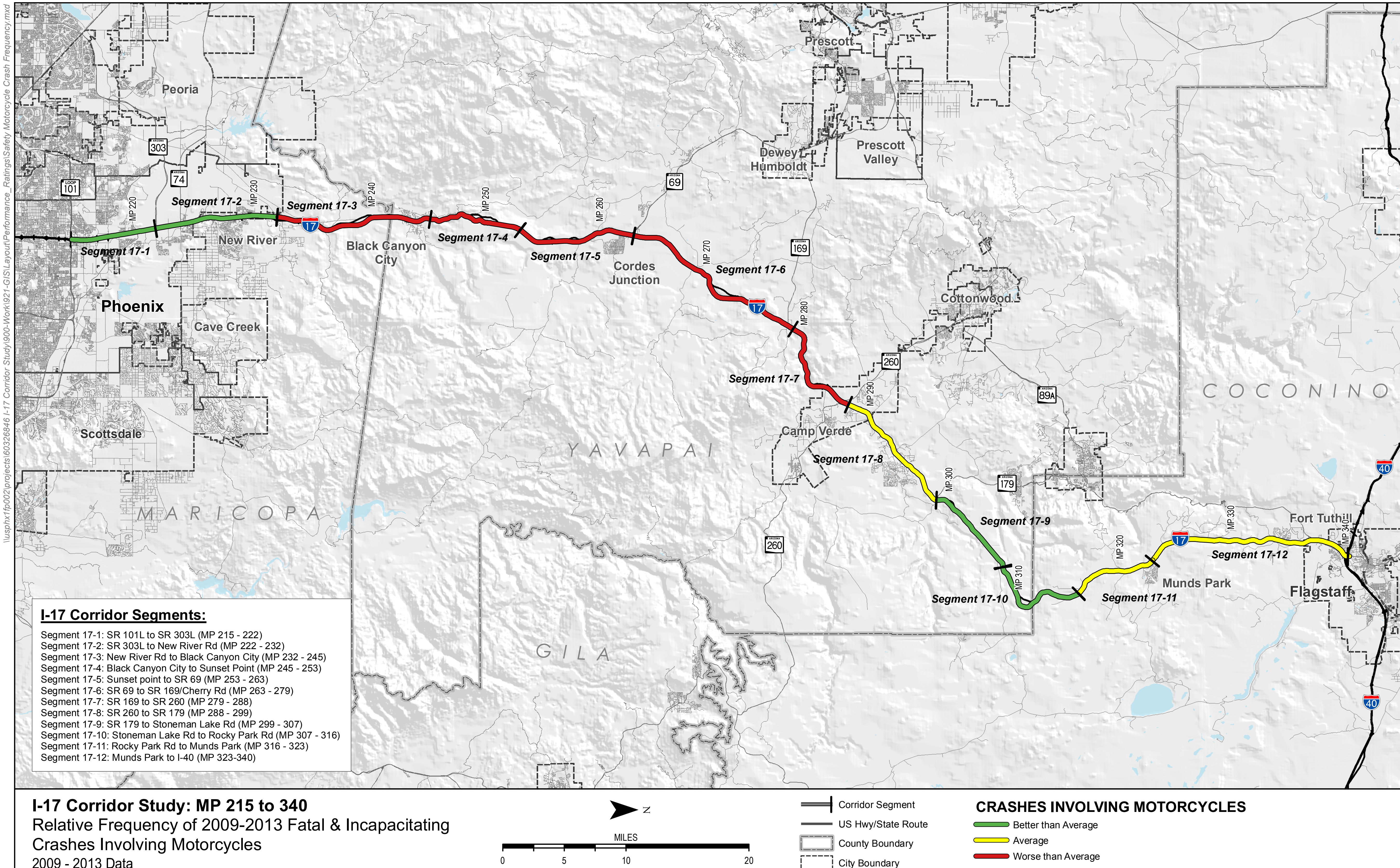
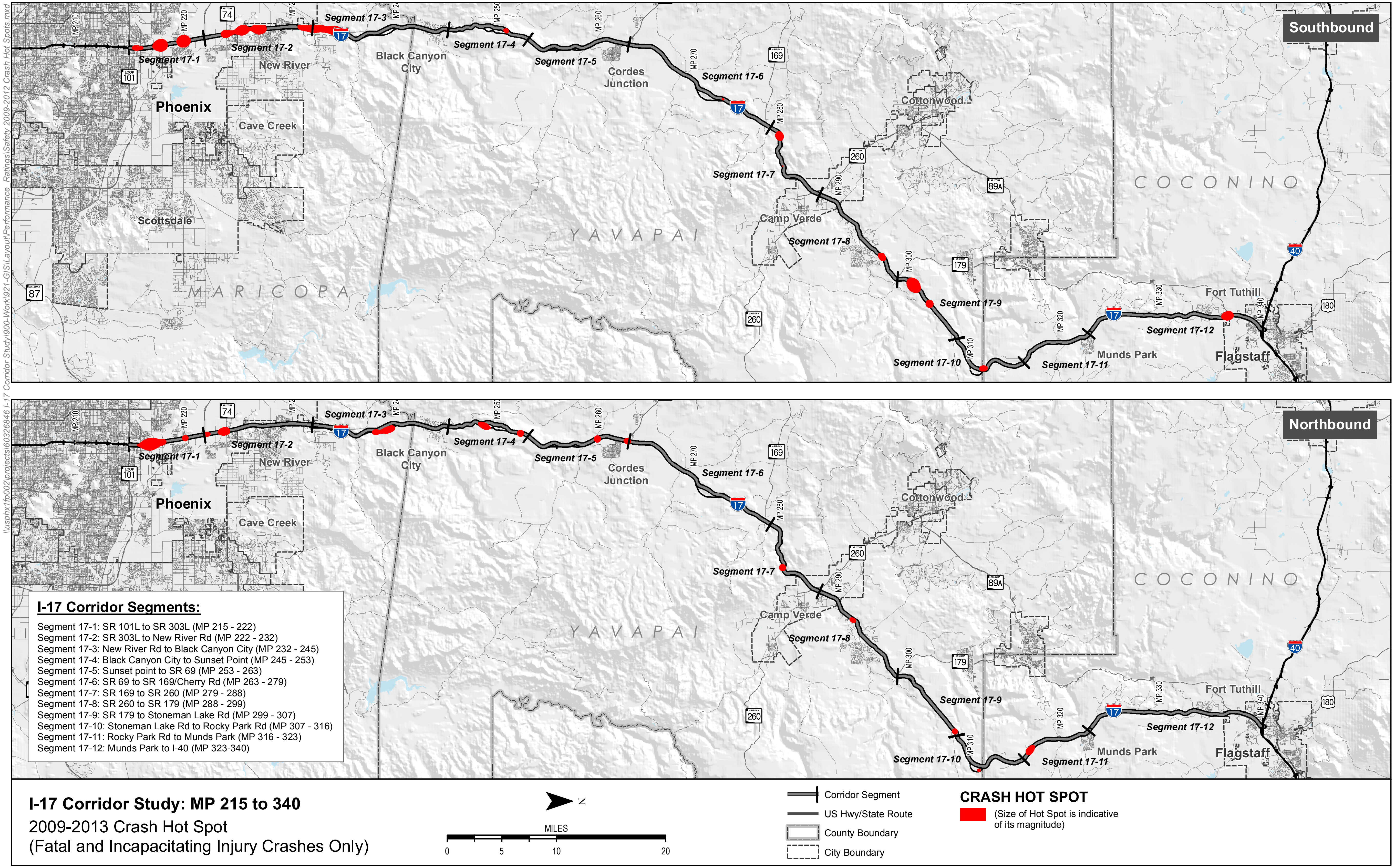


Figure 27 – Crash Hot Spots



3.5. Freight Performance

The Freight Index and secondary performance measures were calculated for the I-17 corridor as described in Section 2.6. The Freight Index, Travel Time Index, and Planning Time Index were calculated based on HERE data provided by ADOT for 2013 and the closure data was provided by ADOT for 2009 to 2013. The Freight Index provides a top-level assessment of the freight mobility for the corridor and for each segment. The four supplemental measures provide more detailed information to assess the freight performance for each segment. The resulting scores are shown in Table 6.

Table 6 – Freight Summary

Segment	Segment Length (miles)	Freight Index	Directional TTI (trucks only)		Directional PTI (trucks only)		Closure Duration (hours/mile/year)
			NB	SB	NB	SB	
17-1	7	0.94	1.03	1.03	1.07	1.07	14.8
17-2	10	0.95	1.02	1.00	1.06	1.04	5.9
17-3	13	0.94	1.01	1.03	1.04	1.09	3.1
17-4	8	0.67	1.34	1.07	1.81	1.16	8.4
17-5	10	0.88	1.09	1.02	1.20	1.07	14.3
17-6	16	0.74	1.03	1.27	1.08	1.61	5.8
17-7	9	0.75	1.07	1.27	1.15	1.52	99.6
17-8	11	0.88	1.08	1.05	1.15	1.11	2.4
17-9	8	0.75	1.29	1.06	1.55	1.13	36.4
17-10	9	0.74	1.25	1.07	1.57	1.15	36.0
17-11	7	0.94	1.03	1.02	1.07	1.06	35.8
17-12	17	0.93	1.05	1.03	1.10	1.06	31.9
Weighted Average		0.85					

The results for the Freight Index and secondary measures are shown in Figures 28 through 31. The results of the freight restriction analysis are shown in Figure 32.

Based on the results of this analysis, the following observations could be made:

- Overall, based on the weighted average of the Freight Index, the freight mobility is in “good” condition
- A majority of the segments show either “good” or “fair” performance in the Freight Index
- The TTI and PTI measures generally show “fair” or “poor” performance in the uphill direction of travel in mountainous areas
- Segment 4 (northbound) has the lowest Freight Index and performs the worst in the TTI and PTI performance measures
- Segment 4 (northbound) appears to have the least reliable travel time as it has the greatest difference between the TTI and PTI
- All of the segments show either “fair” or “poor” performance in the closure performance measure
- Segments 7, 9, 10, 11, and 12 have the longest duration of closures
- There are two locations along the corridor that have a vertical clearance restriction that cannot be by-passed by using ramps, Table Mesa TI (southbound) and McGuireville TI (southbound)

Figure 28 – Freight Index

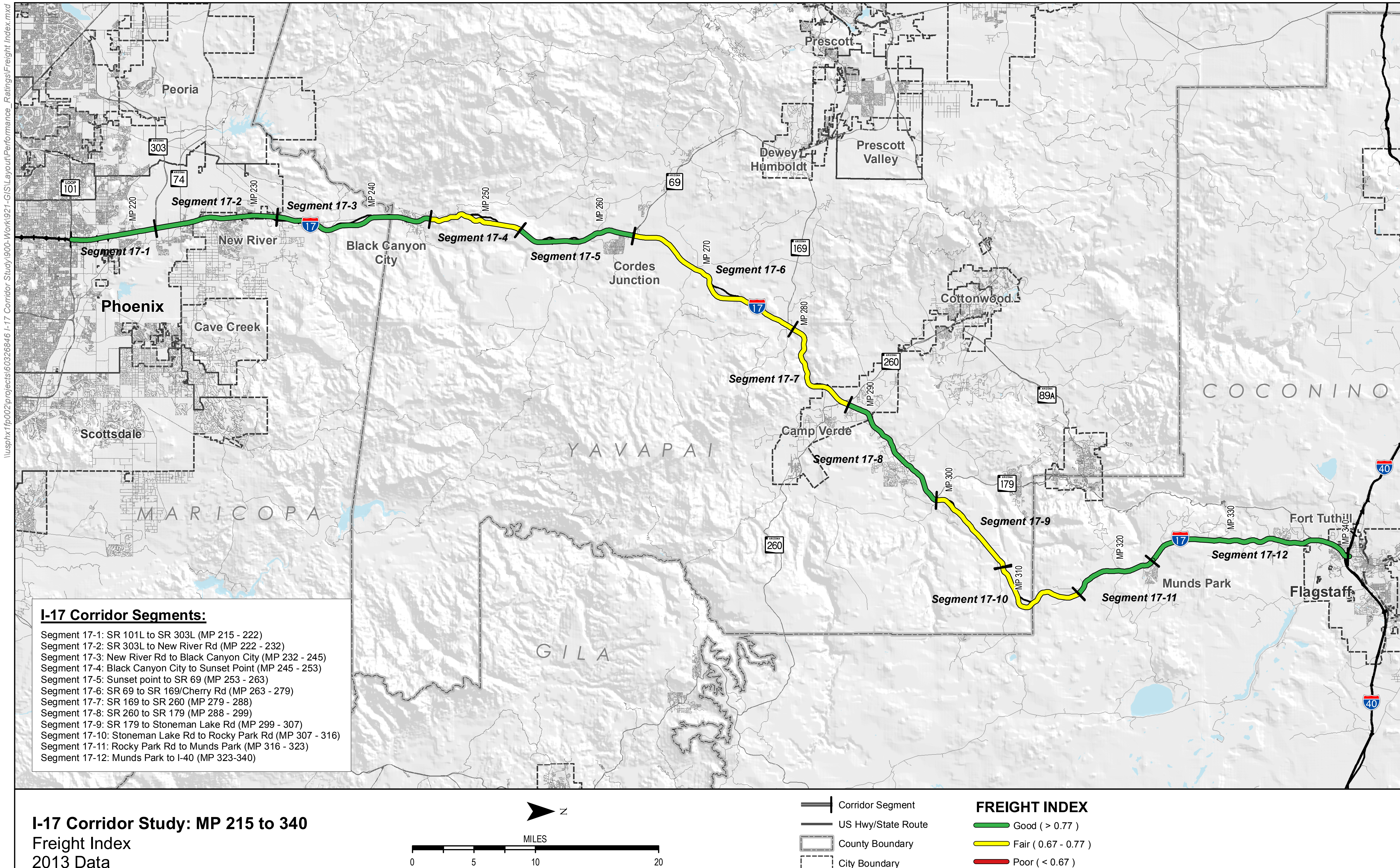


Figure 29 – Truck Travel Time Index

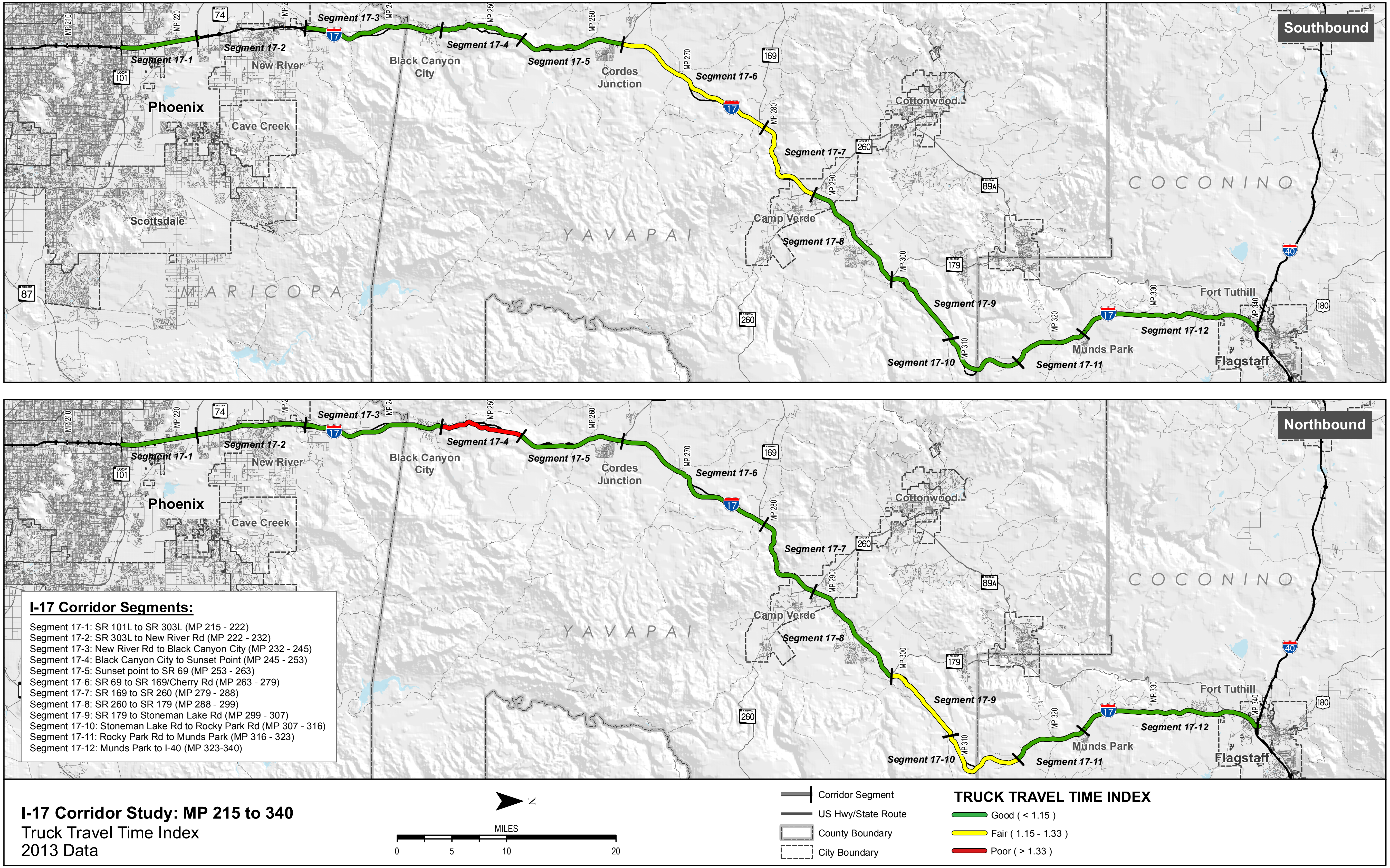


Figure 30 – Truck Planning Time Index

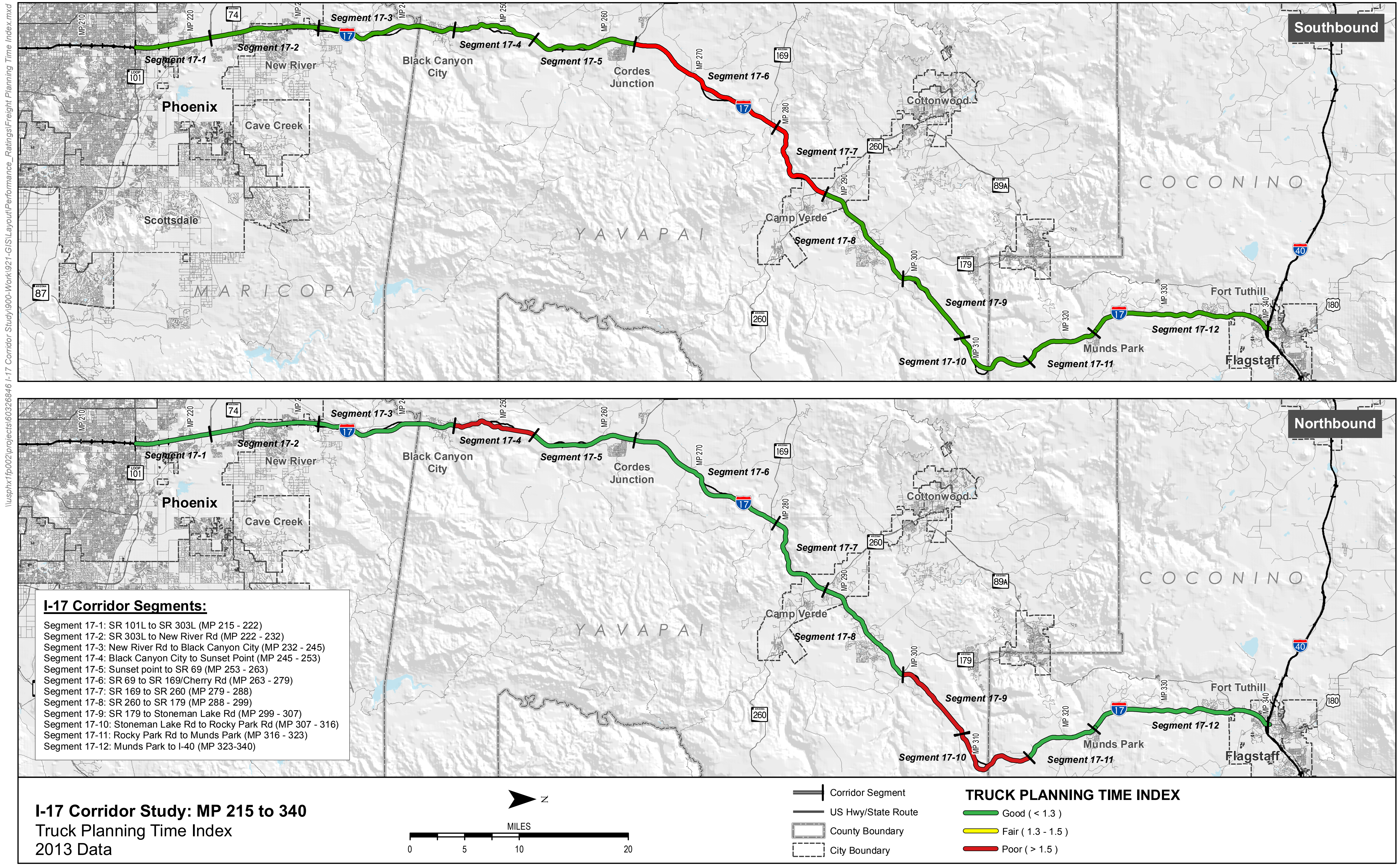


Figure 31 – Duration of Closures

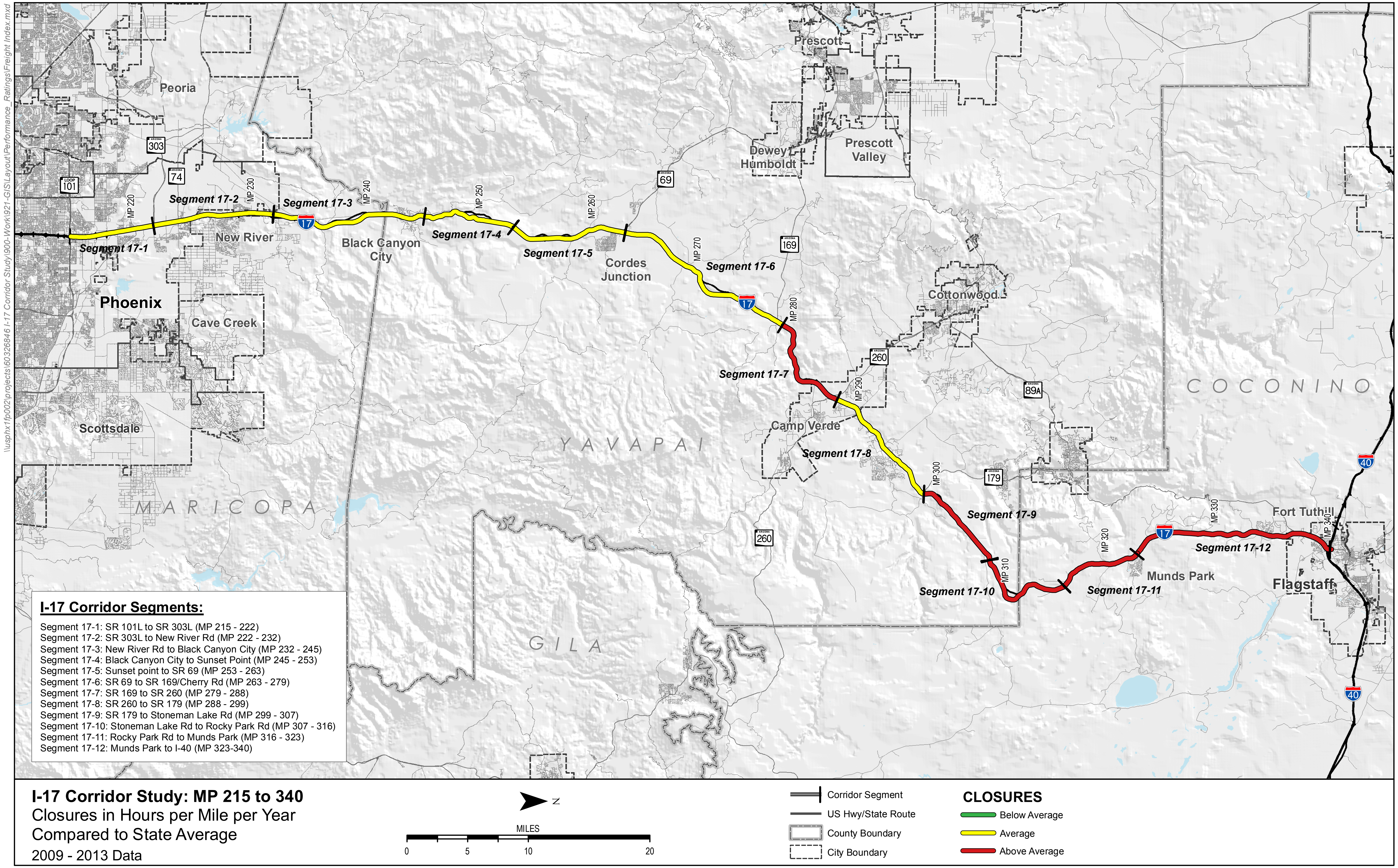
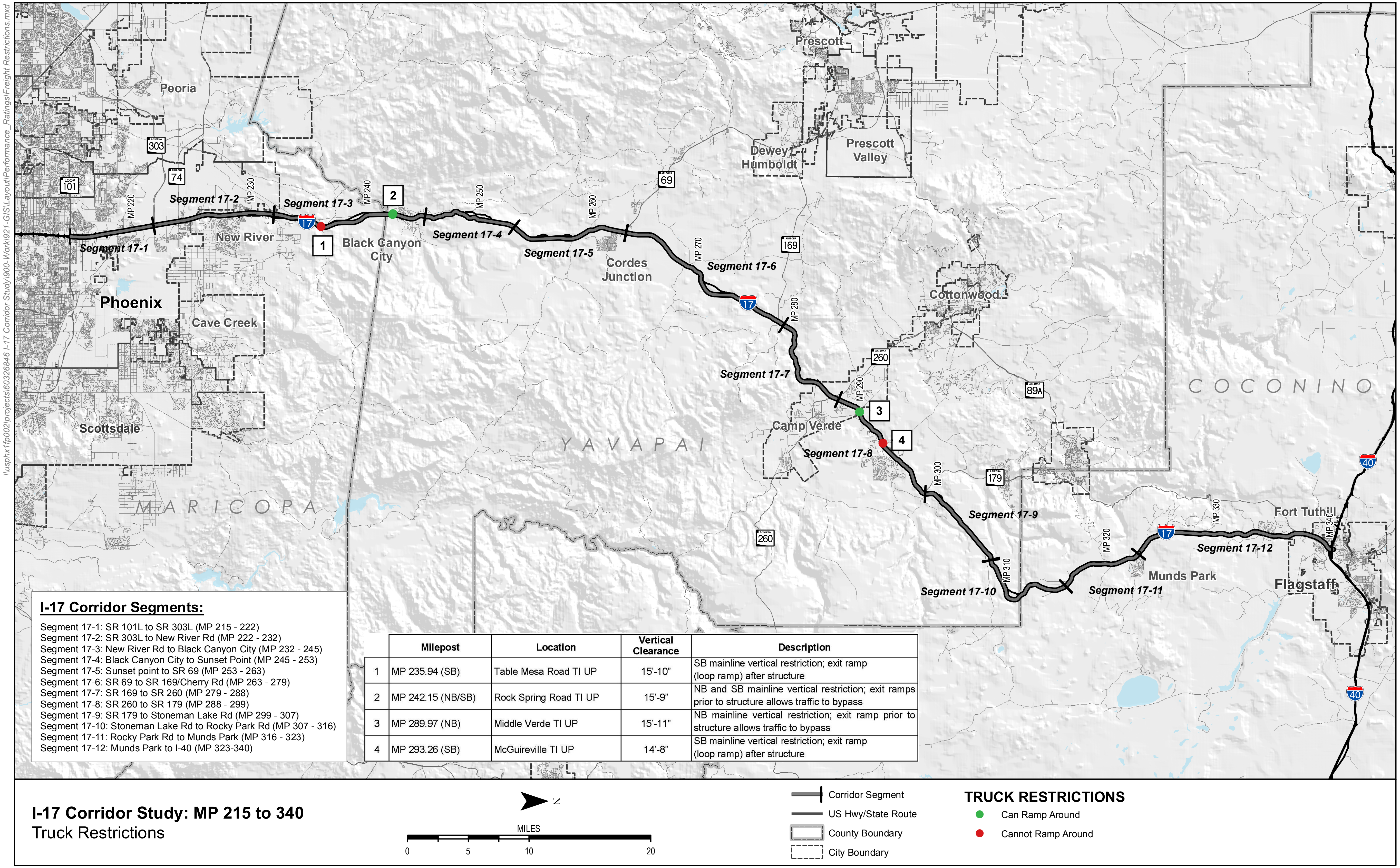


Figure 32 – Vertical Clearance Restrictions



I-17 Corridor Segments:

Segment 17-1: SR 101L to SR 303L (MP 215 - 222)
Segment 17-2: SR 303L to New River Rd (MP 222 - 232)
Segment 17-3: New River Rd to Black Canyon City (MP 232 - 245)
Segment 17-4: Black Canyon City to Sunset Point (MP 245 - 253)
Segment 17-5: Sunset point to SR 69 (MP 253 - 263)
Segment 17-6: SR 69 to SR 169/Cherry Rd (MP 263 - 279)
Segment 17-7: SR 169 to SR 260 (MP 279 - 288)
Segment 17-8: SR 260 to SR 179 (MP 288 - 299)
Segment 17-9: SR 179 to Stoneman Lake Rd (MP 299 - 307)
Segment 17-10: Stoneman Lake Rd to Rocky Park Rd (MP 307 - 316)
Segment 17-11: Rocky Park Rd to Munds Park (MP 316 - 323)
Segment 17-12: Munds Park to I-40 (MP 323-340)

	Milepost	Location	Vertical Clearance	Description
1	MP 235.94 (SB)	Table Mesa Road TI UP	15'-10"	SB mainline vertical restriction; exit ramp (loop ramp) after structure
2	MP 242.15 (NB/SB)	Rock Spring Road TI UP	15'-9"	NB and SB mainline vertical restriction; exit ramps prior to structure allows traffic to bypass
3	MP 289.97 (NB)	Middle Verde TI UP	15'-11"	NB mainline vertical restriction; exit ramp prior to structure allows traffic to bypass
4	MP 293.26 (SB)	McGuireville TI UP	14'-8"	SB mainline vertical restriction; exit ramp (loop ramp) after structure

3.6. Corridor Performance Summary

Based on the results presented in the preceding sections, the following general observations could be made related to the performance of the I-17 corridor:

- The bridges and pavement are generally in “good” or “fair” condition with the exception of a few isolated locations
- The McGuireville TI is a structurally deficient bridge, has a low Sufficiency Rating, and has a sub-standard vertical clearance which obstructs freight movement since the southbound exit ramp is a loop ramp and does not allow trucks to by-pass the restriction
- Currently, the general mobility along the corridor is “good” but projected traffic growth is expected to result in “poor” performance in approximately 40% of the corridor (at the south end and in the middle of the corridor) by the year 2035
- There are several locations along the corridor where recurring and non-recurring delays show either “fair” or “poor” performance, primarily due to uphill grades, as reflected in both the Mobility and Freight Performance Areas
- Currently, the freight mobility along the corridor is “good” with a few spot locations that show “fair” performance primarily due to uphill grades
- The closures along the corridor generally exceed the statewide average for both the closure frequency and duration
- A majority of the segments perform either “fair” or “poor” in the Safety Index
- There are several locations of high crash frequency, including 4 segments in the northbound direction, and 9 segments in the southbound direction

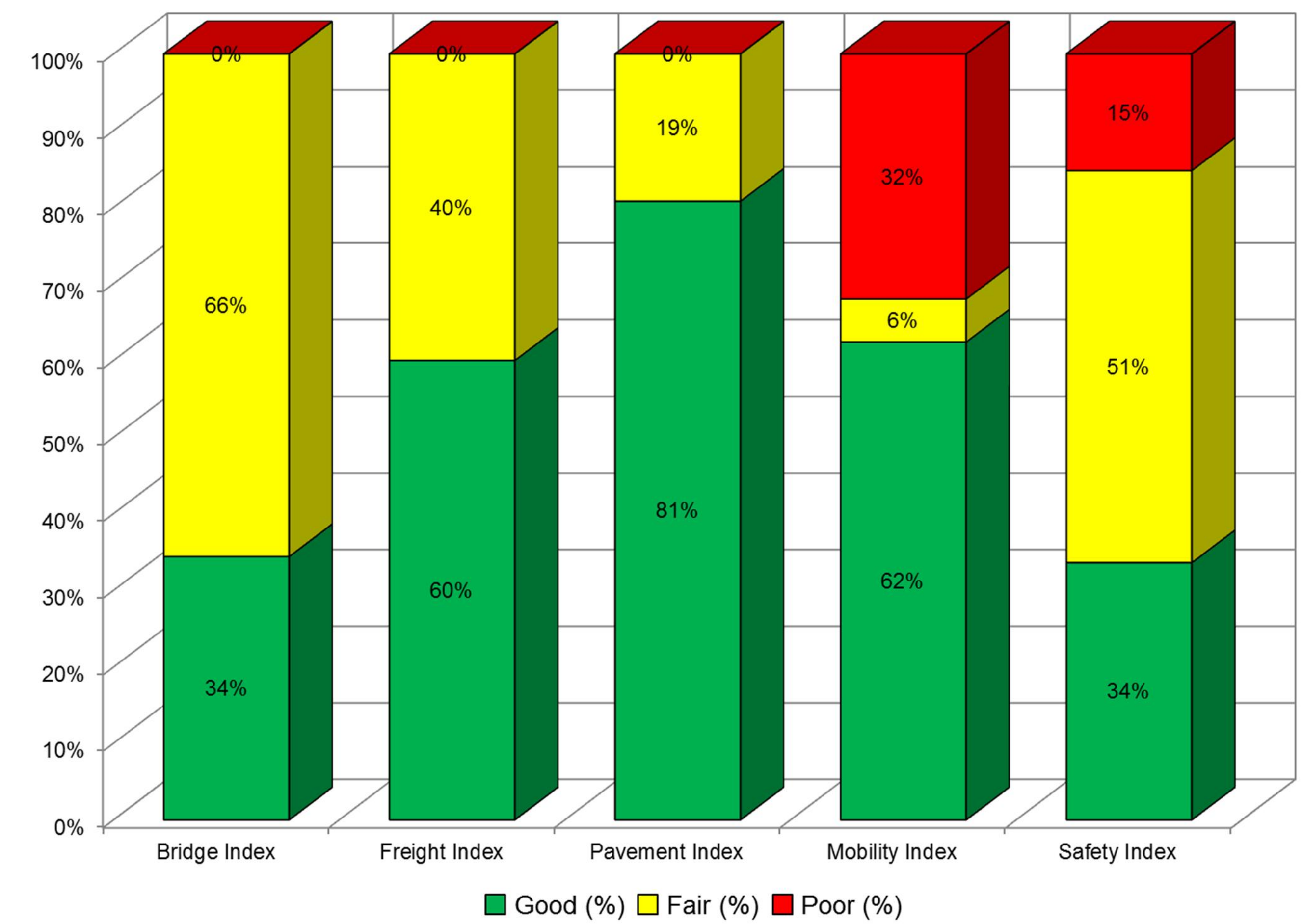
Figure 33 shows the percentage of the I-17 corridor that rates either “good”, “fair”, or “poor” in each Index. Approximately 35% to 80% of the corridor shows “good” performance in the Bridge, Freight, and Pavement Indices while the remaining 20% to 65% shows “fair” performance. In the Mobility and Safety Indices, approximately 15% to 30% of the corridor shows “poor” performance.

It appears that the lowest performance along the I-17 corridor occurs in the Mobility and Safety Performance Areas with the Pavement Performance Area showing the highest performance.

A summary of the Index level performance is shown in Figure 34. Table 7 shows a summary of all primary and secondary performance measures for the I-17 corridor.

Table 7 shows the ratings for each segment of the I-17 corridor. A weighted average rating (based on the length of the segment) was calculated for each primary and secondary measure shown in Table 7. The weighted average ratings are summarized in Figure 35 which also provides a brief description of each performance measure. Figure 35 represents the average for the entire corridor and any given segment or location could have a higher or lower rating than the corridor average.

Figure 33 – Performance Index Distribution



The weekend daily traffic volumes can increase as much as 35% compared to the mid-week volumes. The higher traffic volumes would degrade the traffic operations and result in worse performance than is shown in Table 7 and Figures 33 through 35.

Figure 34 – Corridor Performance Index Summary

	17-1	17-2	17-3	17-4	17-5	17-6	17-7	17-8	17-9	17-10	17-11	17-12	Weighted Average
Pavement	4.19	4.16	3.85	4.25	4.25	4.26	3.92	4.32	4.21	4.19	3.73	3.70	4.07
Bridge	6.76	6.79	6.39	5.71	7.25	6.19	6.31	6.04	6.00	6.52	6.91	5.80	6.34
Mobility	0.75	0.57	0.85	0.87	0.86	0.51	0.78	0.53	0.53	0.43	0.36	0.36	0.60
Safety	0.83	0.77	1.20	0.88	0.94	1.37	1.10	0.71	0.48	1.24	0.87	1.80	1.09
Freight	0.94	0.95	0.94	0.67	0.88	0.74	0.75	0.88	0.75	0.74	0.94	0.93	0.85

I-17 Corridor Study: MP 215 to 340
Performance Index Summary

N
MILES
0 5 10 20

Performance Index Scale

	Pavement	Bridge	Mobility	Safety	Freight
Above Average, Good	> 3.75	> 6.5			> 0.77
Average, Fair	3.2 - 3.75	5.0 - 6.5	Varies	Varies	0.67 - 0.77
Below Average, Poor	< 3.2	< 5.0			< 0.67

Corridor Segment
US Hwy/State Route
County Boundary
City Boundary

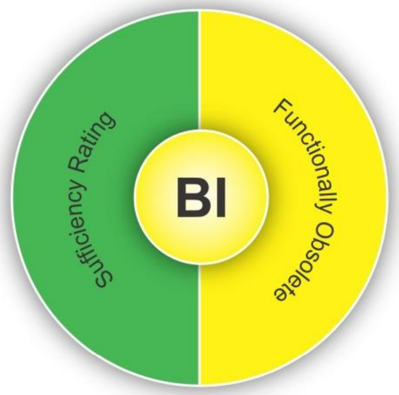
Table 7 – Corridor Performance Summary

Segment	Length (Miles)	Bridge Performance Area			Pavement Performance Area				Mobility Performance Area											Safety Performance Area				Freight Performance Area					
		Bridge Index	Bridge Sufficiency	% Bridge Functionally Obsolete	Pavement Index	Directional PSR		% Area Failure	Mobility Index	Future Daily V/C	Existing Peak Hour V/C		Closure Extent (occurrences/year/ mile)		Directional TTI (all vehicles)		Directional PTI (all vehicles)		% Non-Single Occupancy Vehicle (SOV) Opportunities	Safety Index	% of Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	% of Fatal + Incapacitating Injury Crashes Involving Trucks	% of Fatal + Incapacitating Injury Crashes Involving Motorcycles	Freight Index	Directional TTI (trucks only)		Directional PTI (trucks only)		Closure Duration (hours/mile/ year)
						NB	SB				NB	SB	NB	SB	NB	SB	NB	SB							NB	SB	NB	SB	
17-1	7	6.76	90.95	31.1%	4.19	4.24	4.14	0.0%	0.75	0.91	0.65	0.62	0.95	0.85	1.00	1.00	1.03	1.03	10.7%	0.83	0%	0%	0%	0.94	1.03	1.03	1.07	1.07	14.2
17-2	10	6.79	92.73	14.6%	4.16	4.13	4.15	0.0%	0.57	0.67	0.57	0.55	0.37	0.50	1.07	1.04	1.15	1.11	12.3%	0.77	31%	6%	6%	0.95	1.02	1.00	1.06	1.04	5.9
17-3	13	6.39	91.10	31.3%	3.85	3.92	3.86	3.8%	0.85	1.04	0.56	0.54	0.37	0.25	1.09	1.11	1.17	1.20	12.0%	1.20	69%	10%	14%	0.94	1.01	1.03	1.04	1.09	3.1
17-4	8	5.71	93.97	60.9%	4.25	3.65	4.25	0.0%	0.87	1.07	0.50	0.55	0.70	1.13	1.21	1.00	1.61	1.07	12.3%	0.88	35%	6%	18%	0.67	1.34	1.07	1.81	1.16	8.4
17-5	10	7.25	96.41	15.0%	4.25	4.09	4.02	0.0%	0.86	1.06	0.58	0.57	1.00	1.05	1.20	1.14	1.34	1.21	15.5%	0.94	35%	10%	10%	0.88	1.09	1.02	1.20	1.07	14.3
17-6	16	6.19	94.82	8.5%	4.26	4.08	4.02	0.0%	0.51	0.63	0.37	0.36	0.41	0.53	1.13	1.38	1.23	1.69	7.7%	1.37	56%	6%	17%	0.74	1.03	1.27	1.08	1.61	5.8
17-7	9	6.31	91.41	0.0%	3.92	3.78	3.93	16.7%	0.78	0.96	0.66	0.63	3.21	3.50	1.23	1.15	1.27	1.31	7.7%	1.10	47%	7%	13%	0.75	1.07	1.27	1.15	1.52	99.6
17-8	11	6.04	89.20	13.6%	4.32	4.01	4.17	4.5%	0.53	0.63	0.42	0.43	0.31	0.24	1.14	1.13	1.27	1.24	14.1%	0.71	58%	21%	5%	0.88	1.08	1.05	1.15	1.11	2.4
17-9	8	6.00	93.00	100.0%	4.21	3.77	4.18	18.8%	0.53	0.63	0.30	0.36	2.18	1.55	1.30	1.12	1.61	1.22	6.6%	0.48	48%	10%	0%	0.75	1.29	1.06	1.55	1.13	36.4
17-10	9	6.52	94.00	100.0%	4.19	4.01	4.06	0.0%	0.43	0.51	0.25	0.28	2.19	1.55	1.29	1.13	1.60	1.25	6.3%	1.24	50%	20%	0%	0.74	1.25	1.07	1.57	1.15	36.0
17-11	7	6.91	96.48	3.4%	3.73	3.50	3.82	21.4%	0.36	0.43	0.23	0.26	1.89	1.60	1.10	1.08	1.18	1.16	6.2%	0.87	29%	7%	7%	0.94	1.03	1.02	1.07	1.06	35.8
17-12	17	5.80	92.00	62.3%	3.70	3.49	3.82	25.7%	0.36	0.44	0.23	0.28	1.68	1.37	1.05	1.04	1.13	1.11	17.9%	1.80	33%	4%	8%	0.93	1.05	1.03	1.10	1.06	31.9
Weighted Average	125	6.34			4.07				0.60											1.09				0.85					

Good		> 6.5	> 80	< 15	> 3.75	> 3.75	< 5	< 0.71 (0.56)	< 0.26	< 1.15	< 1.3	≥ 17%	> 1.24	<35% (44%)	<2% (11%)	<9% (5%)	> 0.77	< 1.15	< 1.3	< 0.8
Fair		5.0 - 6.5	50 - 80	15 - 45	3.2 - 3.75	3.2 - 3.75	5 - 20	0.71 - 0.89 (0.56 - 0.76)	0.26 - 1.53	1.15 - 1.33	1.3 - 1.5	11 - 17%	0.76 - 1.24	35%-55% (44%-51%)	2%-6% (11%-16%)	9%-19% (5%-10%)	0.67 - 0.77	1.15 - 1.33	1.3 - 1.5	0.8 - 18.6
Poor		< 5.0	< 50	> 45	< 3.2	< 3.2	> 20	> 0.89 (0.76)	> 1.53	> 1.33	> 1.5	< 11%	< 0.76	>55% (51%)	>6% (16%)	>19% (10%)	< 0.67	> 1.33	> 1.5	> 18.6
								Urban (Rural)						Urban (Rural)						

Figure 35 – Corridor Performance Summary

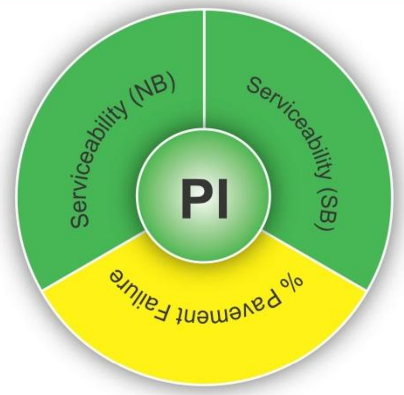
Bridge



Bridge Index (BI) is calculated based on the use of four bridge condition ratings from the ADOT Bridge Database. The four ratings include the Deck Rating, Substructure Rating, Superstructure Rating, and Structural Evaluation Rating.

- **Sufficiency Rating** - numeric value which is indicative of bridge sufficiency to remain in service. The factors that contribute to the Sufficiency Rating include structural adequacy and safety, serviceability and functional obsolescence, and essentiality for public use.
- **Functionally Obsolete** - design of a bridge is no longer functionally adequate for its current use, such as a lack of shoulders or the inability to handle current traffic volumes. Functionally Obsolete does not directly relate to the structural adequacy.

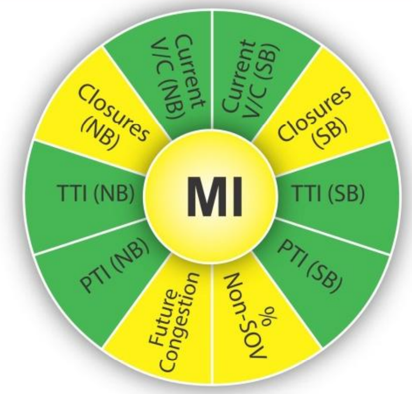
Pavement



Pavement Index (PI) is calculated based on the use of two pavement condition ratings from the ADOT Pavement Database. The two ratings are the International Roughness Index (IRI) and the Cracking Rating. The calculation of the Pavement Index uses a combination of these two ratings.

- **Directional Pavement Serviceability** - calculated as a weighted average (based on number of lanes) and measures the condition of the pavement in each direction of travel.
- **Pavement Failure** - percentage of pavement area that is rated above the failure thresholds for IRI or Cracking, as established by ADOT Materials Group (IRI > 105 or Cracking > 15)

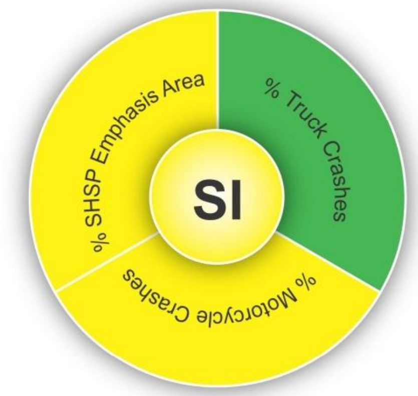
Mobility



Mobility Index (MI) is an average of the current volume to capacity (V/C) ratio and the projected 2035 V/C ratio for each segment throughout the corridor.

- **Peak Congestion** - the existing peak hour V/C ratio in both directions of the corridor. This measure provides an understanding of the directional operating characteristics of the corridor during the existing peak hour.
- **Future Congestion** - is a measurement of the future 2035 V/C ratio and identifies how the corridor will operate in the future from a mobility and congestion standpoint.
- **Directional closures** - average number of times a segment of the corridor was closed per mile in a specific direction of travel per year.
- **Travel Time Index (TTI)** - is the relationship of the average peak period travel time to the free flow travel time. The TTI represents recurring delay that occurs along a corridor.
- **Directional Planning Time Index (PTI)** - the ratio of total travel time needed for 95 percent on-time arrival to free-flow travel time.
- **Non-single occupancy vehicle trips** - represent the number of trips that are taken in a corridor by vehicles carrying more than one passenger.

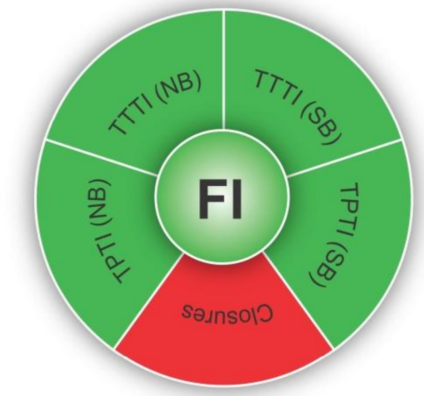
Safety



Safety Index (SI) is based on the bi-directional (i.e., both directions combined) frequency and rate of fatal and incapacitating injury crashes, compared to crash occurrences on similar roadways in Arizona.

- **% SHSP Emphasis Area** - percentage of fatal and incapacitating crashes that involve at least one of the five Strategic Highway Safety Plan (SHSP) Emphasis Areas.
- **% Truck Crashes** - percentage of fatal and incapacitating crashes that involve a truck.
- **% Motorcycle Crashes** - percentage of fatal and incapacitating crashes that involve a motorcycle.

Freight



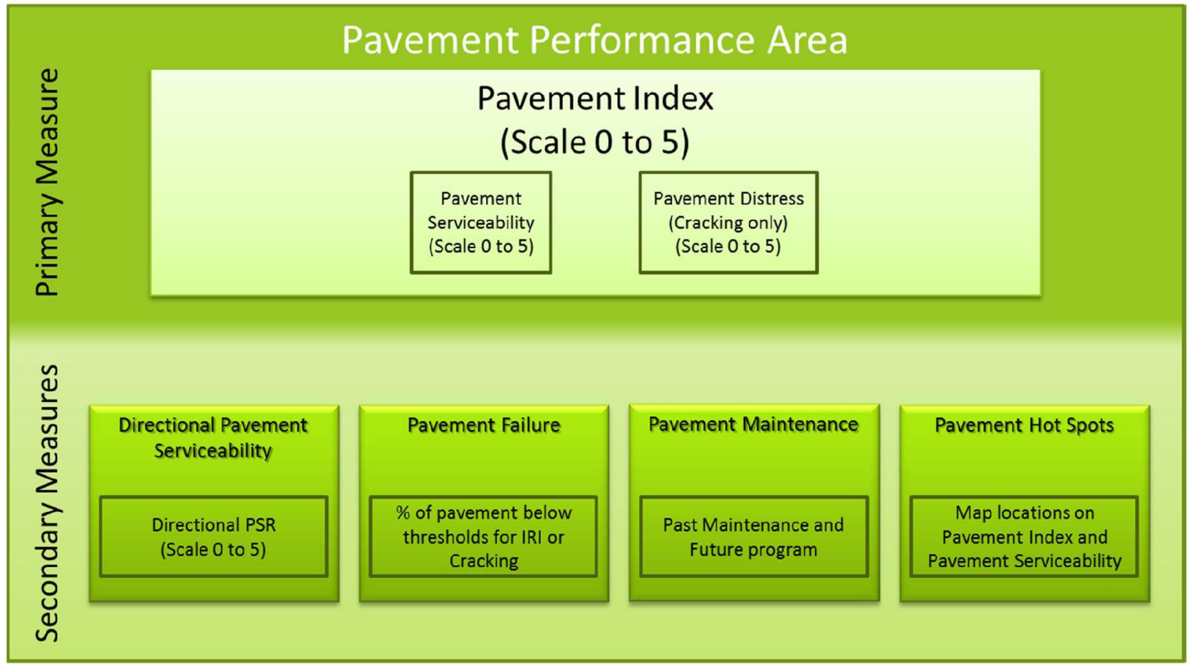
Freight Index (FI) is a reliability performance measure based on the planning time index for truck travel.

- **Directional Truck Planning Time Index (TPTI)** - the ratio of total travel time (for trucks only) needed for 95 percent on-time arrival to free-flow travel time.
- **Directional Truck Travel Time Index (TTTI)** - is the relationship of the average peak period travel time (for trucks only) to the free flow travel time. The TTI represents recurring delay that occurs along a corridor.
- **Closures** - average roadway closure duration time.

LEGEND: Good/Better than Average Performance; Fair/Average Performance; Poor/Worse than Average Performance

Appendix A – Performance Area Instructions

PAVEMENT PERFORMANCE AREA



Primary Measure:
The Pavement Index is calculated based on the use of two pavement condition ratings from the ADOT Pavement Database. The two ratings are the International Roughness Index (IRI) and the Cracking Rating. The calculation of the Pavement Index uses a combination these two ratings.

The IRI is a measurement of the pavement roughness based on field-measured longitudinal roadway profiles. To facilitate the calculation of the index, the IRI rating was converted to a Pavement Serviceability Rating (PSR) using the following equation:

$$PSR = 5 * e^{-0.0038*IRI}$$

The Cracking Rating is a measurement of the amount of surface cracking based on a field-measured area of 1,000 square feet that serves as a sample for each mile. To facilitate the calculation of the index, the Cracking Rating was converted to a Pavement Distress Index (PDI) using the following equation:

$$PDI = 5 - (0.345 * C^{0.66})$$

Both the PSR and PDI use a 0 to 5 scale with 0 representing the lowest performance and 5 representing the highest performance. The performance thresholds shown in the table below were used for the PSR and PDI.

	IRI (PSR)	Cracking (PDI)
Good	<75 (>3.75)	<7 (>3.75)
Fair	75 - 117 (3.20 - 3.75)	7 - 12 (3.22 - 3.75)
Poor	>117 (<3.20)	>12 (<3.22)

The PSR and PDI are calculated for each 1-mile section of roadway. If PSR or PDI falls into a poor rating (<3.2) for a 1-mile section, then the score for that 1-mile section is entirely (100%) based on the lower score (either PSR or PDI). If neither PSR or PDI fall into a poor rating for a 1-mile section, then the score for that 1-mile section is based on a combination of the lower rating (70% weight) and the higher rating (30% weight). The end result is a score between 0 and 5 for each direction of travel of each mile of roadway based on a combination of both the PSR and the PDI.

The project corridor has been divided into segments. The Pavement Index for each segment is a weighted average of the directional ratings based on the number of travel lanes. Therefore, the condition of a section with more travel lanes will have a greater influence on the resulting segment Pavement Index than a section with fewer travel lanes.

The resulting Pavement Index (good/fair/poor) for each segment will be presented on a corridor map. In addition, the calculated Pavement Index for each segment will be presented in tabular format.

Secondary Measures:
Two secondary measures will be evaluated:

- Directional Pavement Serviceability
- Pavement Failure

Directional Pavement Serviceability: Similar to the Pavement Index, the Directional Pavement Serviceability will be calculated as a weighted average (based on number of lanes) for each segment. However, this rating will only utilize the PSR and will be calculated separately for each direction of travel. The PSR uses a 0 to 5 scale with 0 representing the lowest performance and 5 representing the highest performance. The resulting Directional Pavement Serviceability (good/fair/poor) for each direction of each segment will be presented on a corridor map. In addition, the calculated Directional Pavement Serviceability for each segment will be presented in tabular format.

Pavement Failure: The percentage of pavement area rated above the failure thresholds for IRI or Cracking will be calculated for each segment. The calculated percentage for each segment will be presented in a table. In addition, the Standard score (z-score) will be calculated for each segment.

The Standard score (z-score) is the number of standard deviations above or below the mean. Therefore, a Standard score between -0.5 and +0.5 is “average”, less than -0.5 is lower (better) than average, and higher than +0.5 is above (worse) average. The resulting Standard Score (better/average/worse) for each segment will be presented on a corridor map.

Hot Spot Identification:
The Pavement Index map will identify locations that have an IRI rating or Cracking rating that fall above the failure threshold as identified by ADOT Pavement Group. An IRI rating above 105 or a Cracking rating above 15 will be used as the thresholds which are slightly different than the ratings shown in the table above. The locations will be identified by displaying a symbol on the map. A single symbol will be used to represent consecutive/adjacent sections. However, if there is a gap between the sections, then a second symbol will be displayed on the map.

The Directional Serviceability map will identify locations that have an IRI rating above 105 by displaying a symbol and labeling the location. A single symbol will be used to represent consecutive/adjacent sections. However, if there is a gap between the sections, then a second symbol will be displayed on the map.

Data Entry:
1. Edit the data in Column A (add or delete rows and edit titles in Column A) to match the correct number of 1-mile sections within the segment and copy the formulas in columns B and D
2. Enter the beginning milepost for Mile 1 and the other mileposts should auto-calculate
3. Edit the titles in cells E-1, H-1, K-1, and M-1 to reflect the directions of travel
4. Copy and paste 2 pavement ratings (IRI and Cracking) for each 1-mile section into the appropriate cells; use the "paste values" command to not overwrite formatting
5. If the 1-mile section does not have a Cracking rating, enter 0.1 into the cell for Cracking
6. Enter the number of lanes for each 1-mile section into columns E and H; it is suggested that this number be a rounded approximation and not based on as-builts
7. If rows are added, copy the formulas
8. If the formatting doesn't work, use the "format painter" tool to copy the formatting from other cells

Calculations:
1. Columns K through N calculate the PSR and PDI for each 1-mile section for each direction of travel
2. Columns O and P calculate a composite rating for each 1-mile section based on a combination of PSR and PDI
3. The weighted average Pavement Index (weighted by number of lanes) is calculated in Column Q
4. The weighted average PSR (weighted by number of lanes) is calculated in Columns K and M
5. The % of pavement above the thresholds for failure is calculated in Column S

Resulting Values and Presentation:
1. Pavement Index rating for each segment (good/fair/poor) presented on map with red symbol at locations of failing pavement (either IRI or Cracking)
2. Pavement Index score presented in table
3. Directional Pavement Serviceability for each segment in each direction (good/fair/poor) presented on map with red symbol at locations that have an IRI above 105
4. Directional Pavement Serviceability score presented in table
5. % Failing Pavement; % presented in table; Standard score presented on map.

Scoring:

Pavement Index	
Good	>3.75
Fair	3.2 - 3.75
Poor	<3.2

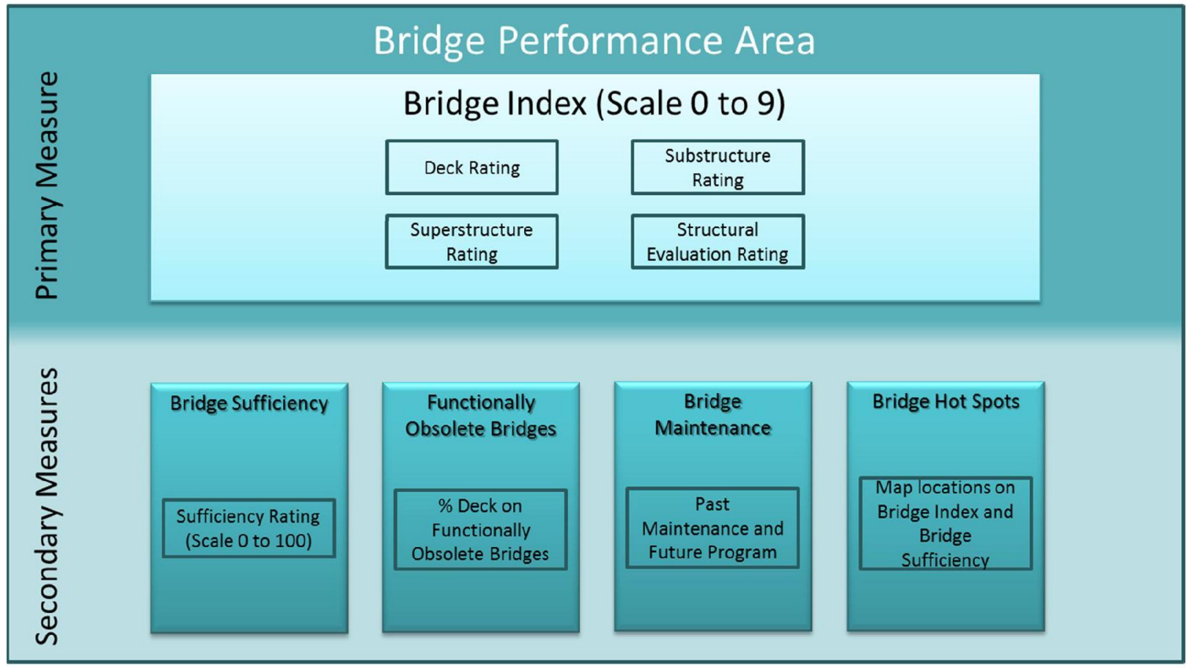
Directional Pavement Serviceability	
Good	>3.75
Fair	3.2 - 3.75
Poor	<3.2

Standard Score (1)	
Better	< -0.5
Average	-0.5 – +0.5
Worse	>+0.5

(1) The Standard score (z-score) is based on the % of pavement rated above failure threshold for each segment.

Example Calculation for Pavement Performance Area:
See the attached example for the Pavement Performance Area.

BRIDGE PERFORMANCE AREA



<u>Primary Measure:</u>
The Bridge Index is calculated based on the use of four bridge condition ratings from the ADOT Bridge Database, also known as the Arizona Bridge Information and Storage System (ABISS). The four ratings are the Deck Rating (N58), Substructure Rating (N60), Superstructure Rating (N59), and Structural Evaluation Rating (N67). The calculation of the Bridge Index uses the lowest of these four ratings.

Each of the four condition ratings use a 0 to 9 scale with 0 representing the lowest performance and 9 representing the highest performance. As defined by ADOT Bridge Group, a rating of 7 or above represents “good” performance, a rating of 5 or 6 represents “fair” performance, and a rating of 4 or below represents “poor” performance.

The project corridor has been divided into segments and the bridges are grouped together according to the segment definitions. In order to report the Bridge Index for each corridor segment, the Bridge Index for each segment is a weighted average based on the deck area for each bridge. Therefore, the condition of a larger bridge will have a greater influence on the resulting segment Bridge Index than a smaller bridge.

The resulting Bridge Index (good/fair/poor) for each segment will be presented on a corridor map. In addition, the calculated Bridge Index for each segment will be presented in tabular format.

<u>Secondary Measures:</u>
Two secondary measures will be evaluated:

- Bridge Sufficiency Rating
- Functionally Obsolete Bridges

Bridge Sufficiency Rating: Similar to the Bridge Index, the Bridge Sufficiency Rating will be calculated as a weighted average (based on deck area) for each segment. The Sufficiency Rating is a scale of 0 to 100 with 0 representing the lowest performance and 100 representing the highest performance. A rating of 80 or above represents “good” performance, a rating between 50 and 80 represents “fair” performance, and a rating below 50 represents “poor” performance. The resulting Sufficiency Rating (good/fair/poor) for each segment will be presented on a corridor map. The calculated Sufficiency Rating for each segment will be presented in tabular format.

Functionally Obsolete Bridges: The percentage of deck area on functionally obsolete bridges will be calculated for each segment. The deck area for each bridge within each segment that has been identified as functionally obsolete will be totaled and divided by the total deck area for the segment to calculate the percentage of deck area on functionally obsolete bridges for each segment. The calculated percentage for each segment will be presented in tabular format. In addition, the Standard score (z-score) will be calculated for each segment.

The Standard score (z-score) is the number of standard deviations above or below the mean. Therefore, a Standard score between -0.5 and +0.5 is “average”, less than -0.5 is lower (better) than average, and higher than +0.5 is above (worse) average. The resulting Standard Score (better/average/worse) for each segment will be presented on a corridor map.

<u>Hot Spot Identification:</u>
The Bridge Index map will identify individual bridge locations that are rated as Structurally Deficient (identified as “S” in column labeled DeficiencyClassification) by displaying a symbol and labeling the location. The Sufficiency Rating map will identify individual bridge locations that have a Sufficiency Rating less than 50 by displaying a symbol and labeling the location.

<u>Data Entry:</u>
1. Copy and paste bridge names (A209) in rows for each segment; use the “paste values” command to not overwrite formatting
2. Copy and paste 4 bridge ratings (N58, N59, N60, N67) for each bridge into the appropriate cells; use the “paste values” command to not overwrite formatting; values in bridge file are input as “general” format so after the values are pasted into the cells, they need to have their format converted to “numbers”
3. Copy and paste Sufficiency Rating (SufficiencyRating) for each bridge into the appropriate cells in Column E; use the “paste values” command to not overwrite formatting
4. Copy and paste Deck Area (A225) for each bridge into the appropriate cells in Column D; use the “paste values” command to not overwrite formatting
5. If the bridge has been identified as Functionally Obsolete (identified as “F” in in column labeled DeficiencyClassification), manually enter the deck area in column K
6. If rows are added, copy the formulas
7. If the formatting doesn’t work, use the “format painter” tool to copy the formatting from other cells

Note: Only enter data for the mainline bridges. Bridges on ramps, frontage roads, etc. should not be used. In addition, structures with “SPP” or “RCB” in the name (A209) should not be entered.

Calculations (automated):

1. Column D is the deck area and the values are added together to get a total deck area for the segment.
2. Columns F through I are the 4 bridge ratings; column J identifies the lowest value from the 4 bridge ratings
3. The weighted average Sufficiency Rating (weighted by deck area) and the weighted average Condition Rating (weighted by deck area) are calculated

Resulting Values and Presentation:

1. Bridge Index rating for each segment (good/fair/poor) presented on map with red symbol at locations that are structurally deficient
2. Bridge Index scores presented in table
3. Sufficiency Rating for each segment (good/fair/poor) presented on map with red symbol at locations that have a Sufficiency Rating less than 50
4. Sufficiency Rating scores presented in table
5. % Bridge Deck Area on Functionally Obsolete Bridges; % presented in table; Standard score presented on map.

Scoring:

Bridge Index	
Good	>6.5
Fair	5.0-6.5
Poor	<5.0

Sufficiency Rating	
Good	>80
Fair	50-80
Poor	<50

Standard Score (1)	
Better	< -0.5
Average	-0.5 – +0.5
Worse	>+0.5

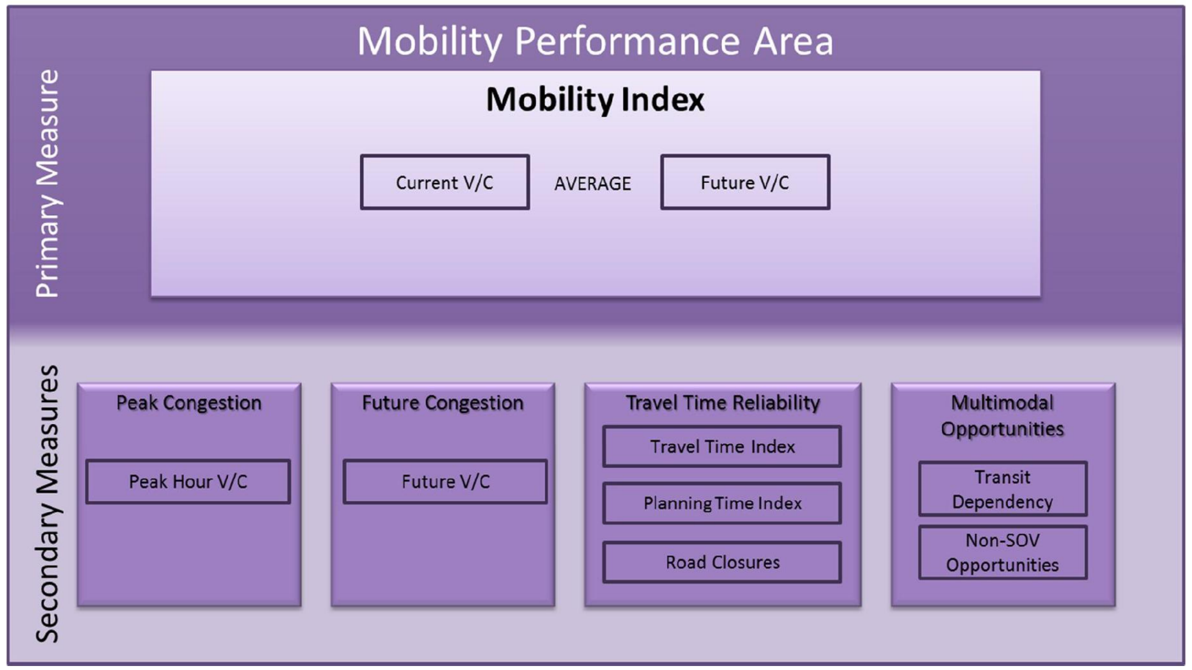
(1) The Standard score (z-score) is based on the % of deck area on Functionally Obsolete Bridges for each segment.

Example Calculation for Bridge Performance Area:

See the attached example for the Bridge Performance Area.

Mobility Performance Area Definitions and Methods

This Appendix summarizes the approach and methodology to develop the primary and secondary performance measures in the Mobility Performance Area as shown in the following graphic.



Primary Measure

The primary Mobility Index is an average of the current volume to capacity (V/C) ratios and the projected future V/C ratios for each segment throughout the corridor.

Current V/C

The current V/C ratio for each segment is calculated by dividing the 2013 Annual Average Daily Traffic (AADT) volume for each segment by the total Level of Service (LOS) E capacity volume for that segment as defined by the Florida Department of Transportation (FDOT) LOS Handbook Tables. The AADT for each segment is calculated by applying a weighted average across the length of the segment based on the individual 24 hour volumes and distances associated with each HPMS count station within each segment. The segment capacity is defined based on the characteristics of each segment including Number of Lanes, Terrain Type, and Environment, which are linked to a generalized capacity volume in the FDOT tables.

The following example equation was used to determine the weighted average of a segment with two HPMS count locations within the corridor

((HPMS 1 Distance x HPMS 1 Volume)+(HPMS 2 Distance x HPMS 2 Volume))/Total Segment Length

Future V/C

The future V/C ratio for each segment is calculated by dividing the 2035 AADT volume for each segment by the 2013 LOS E capacity volumes for that segment as defined by the FDOT LOS tables. The capacity volume used in this calculation is the same number as was used in the current V/C equation to understand how projected future volumes would work in the existing environment. The future AADT volumes are generated by applying an annual compound growth rate (ACGR) to each 2013 AADT segment volume. The following equation was used to apply an annual compound growth rate:

2035 AADT = 2013 AADT x ((1+ACGR)^22)

The ACGR for each segment was defined by comparing the total volumes in the 2010 Arizona Travel Demand Model (AZTDM2) to the 2035 AZTDM2 traffic volumes at each existing HPMS count station location throughout the corridor. Each 2010 and 2035 segment volume was defined using the same weighted average equation described in the *Current V/C* section above then summing the directional volumes for each location. The following equation was used to determine the ACGR for each segment:

ACGR = ((2035 Volume/2010 Volume)^(1/25))-1

Primary Index Data Entry

1. In tab 'HPMS Report 2013R,' use the filter function in Column 'C' to show all records for your respective corridor.
2. In tab 'HPMS Report 2013R,' copy all records for Columns A (Loc ID), D (BMP), G (EMP), J (Pos Dir AADT), K (Neg Dir AADT) , L (AADT 2013), and P (K Factor).
   Note: If the directional AADT values are not provided for a specific HPMS count location, apply the average ratio of the upstream and downstream HPMS count location directional values to their respective two way value. On I-19, this formula is highlighted in cells where it occurred in yellow.
3. Paste copied values into appropriate columns in tab '2013 HPMS'
4. On tab '2013 HPMS' in columns B, C, and D input corridor specific information for each respective segment.
5. On tab '2013 HPMS' in columns E, F, G, and H apply the weighted average formula referenced in the *Current V/C* section to each count location in each corridor segment to calculate the corresponding segment values for the following data:
   a. 2013 AADT (Column E)
   b. NB AADT (Column F)
   c. SB AADT (Column G)
   d. K Factor (Column H).
   Note: Adjust the formulas saved in columns E through G for the appropriate number of count stations in each segment. Column I (AADT 2013) on 'Mobility Index' tab will auto populate with appropriate values.

6. On tab 'Mobility Index' define the Facility Type, Terrain, and Number of Lanes for each segment using the drop down arrow in each cell. Use the following methodologies to determine Facility Type and Terrain for each segment as defined by the FDOT LOS Handbook Tables and the ADOT Roadway Design Guidelines:

   Facility Type
   a. **Urban** – Generally fully developed area, mile spaced TI's, and a 65 mph speed limit.
   b. **Fringe Urban** – more than 5,000 populations not in an urban area, moderate levels of development and a speed limit that is transitioning from 65mph to faster speeds.
   c. **Rural** – Less than 5,000 population, low levels of development, and a 75 mph speed limit

   Terrain Type
   a. **Level** – Any combination of geometric design elements that permits trucks to maintain speeds that equal or approach speeds of passenger cars.
   b. **Rolling** – Any combination of geometric design elements that causes trucks to reduce speed substantially below that of passenger cars on some sections of the highway but which does not involve sustained crawl speeds by trucks for a substantial distance.
   c. **Mountainous** – Any combination of geometric design elements that will cause trucks to operate a crawl speed for considerable distances or at frequent intervals.

7. On tab 'Mobility Index' Column K (Capacity Volume LOS E) will auto populate capacity values from 'Lookup Table' tab based on inputs in Columns F, G, and H.
8. On tab 'HPMS Report 2013R' copy values in column F (TCS MP) and paste in column R (Milepost) on tab '2010'.
9. Using the 2010 AZTDM2 file provided by ADOT, identify the NB and SB total flow for each milepost location segment identified in Column R. Input values in Columns S and T on tab '2010'.
10. On tab '2010,' using the weighted average formulas saved in column D (Tot_Flow), identify the total segment volume for each corridor segment in each direction.
    Note: Adjust the formulas in column D to correspond to the number of milepost location data from the AZTDM2 as necessary. The I-19 example identifies this relationship to calculate the total segment volume in column D for varying numbers of milepost locations.
11. On tab '2010,' using formula saved starting in Column D, Row 20, add NB and SB values to create a 2010 total flow value for each corridor segment.
12. On tab '2035' repeat steps 8, 9, and 10 using the 2035 AZTDM2 file provided by ADOT.
13. On tab '2010' copy formula as necessary to include all segment values in both 2010 and 2035 to calculate Annual Compound Growth Rate (highlighted in blue) for each segment.

14. On tab 'Mobility Index' columns J (AADT 2035), L (Current Segment V/C), M (Future Segment V/C), and N (Avg V/C) will auto populate with based on saved formulas to provide the Primary Index values and ratings (green, yellow, red).

Primary Index Rating Thresholds

The following V/C thresholds were assigned for each environment type as indicated based on current ADOT roadway design standards.

Urban and Fringe Urban

Good - LOS A-C	V/C ≤ 0.71
Fair - LOS D	V/C > 0.71 & ≤ 0.89
Poor - LOS E or less	V/C > 0.89

*Note - ADOT Roadway Design Standards indicate Urban and Fringe Urban roadways should be designed to level of service C or better

Rural

Good - LOS A-B	V/C ≤ 0.56
Fair - LOS C	V/C > 0.56 & ≤ 0.76
Poor - LOS D or less	V/C > 0.76

*Note - ADOT Roadway Design Standards indicate Rural roadways should be designed to level of service B or better

Secondary Measures

Peak Congestion

Peak Congestion has been defined as the peak hour V/C ratio in both directions of the corridor. The peak hour V/C ratio is calculated by dividing the directional design hour volume (DHV) by the directional LOS E capacity volume as defined by the FDOT Generalized LOS Handbook Tables. The DHV is calculated by applying the directional K Factor to the directional 24hr AADT for that segment. The directional AADT for each segment is calculated by applying a weighted average across the length of the segment based on the individual directional 24 hour volumes and distances associated with each HPMS count station within each segment. The segment capacity is defined based on the characteristics of each segment including Number of Lanes, Terrain Type, and Environment, similar to the 24 hour volumes which are linked to a generalized capacity volume in the FDOT tables.

Peak Hour Data Entry

1. On tab '2013 HPMS,' in columns U and V, using the online TDM tool at http://www.azdot.gov/planning/DataandAnalysis input the directional K factors for each HPMS location by referencing the number in the 'Loc ID' column for your corridor.
   Note: If the directional K values are not provided for specific a HPMS count location, apply the average ratio of the upstream and downstream HPMS count location directional values to their respective two way K factor value. On I-19, this formula is highlighted in cells where it occurred in yellow.
2. On tab '2013 HPMS,' columns I (NB K) and J (SB K) will auto fill based on the weighted average formula saved in those cells.

Note: Adjust formulas as needed to account from the appropriate number of input values for each segment. In cases where the directional K factors from ADOT data seem inconsistent with the upstream or downstream count stations, omit or augment data as necessary in an effort to provide an accurate reflection of the total segment directional K factors.

3. On tab 'Mobility Index,' Columns P (NB DHV), Q (NB Capacity LOS E), R (Current NB Peak V/C), S (SB DHV), T (SB Capacity LOS E), and U (Current SB Peak V/C) will all auto fill based on saved formulas in those cells to provide the directional V/C ratios and threshold ratings (green, yellow, red).

Peak Congestion Rating Thresholds

The same thresholds identified for the 24hr V/C ratios were applied to the Peak Congestion V/C values.

Future Congestion

The future V/C ratios for each segment in the corridor that were calculated and used in the Primary Mobility Index as part of the overall average between Current V/C and Future V/C were applied independently as a secondary measure. The methods to calculate the Future V/C can be referenced in the Primary Mobility Index section.

Travel Time Reliability

Travel time reliability is a measure that includes the number of times a piece of a corridor is closed for any specific reason, the directional Travel Time Index (TTI), and the Planning Time Index (PTI).

Directional Closures

The number of times a roadway is closed is documented through the HCRS dataset. Directional Closures was defined as the average number of times a segment of the corridor was closed per year mile in a specific direction of travel per year. The weighted average of each occurrence takes into account the distance over which a specific occurrence spans.

Note: Where closures occur over a distance that spans segment boundaries make sure to include the appropriate distance in each segment. This will require adding an entry into the dataset. For example, if a closure occurs at milepost 10 in a segment that ends at milepost 12 and spans 4 miles you will account for a 2 mile closure in each adjoining segment.

Directional Closures Data Entry

1. Using the 'hcrs_FullClosures_rev4_statewide averages' dataset provided, copy and paste every column of data for ONLY your corridor into the full Mobility Index workbook tab 'HCRS 2009-2013.'
   Note: Make sure to match column headings from each file before copying data from original file.
2. In tab 'HCRS 2009-2013,' sort Column S (hwy_at_mp) from smallest to largest value.

3. Using the milepost location identified in Column S, input the appropriate segment location for each incident in Column R (Segment) in order to breakdown how many closures occurred in each corridor segment.
4. On tab 'Mobility Index' columns W and X will auto fill the average number of incidents that have occurred per mile per year within each segment.

Directional Closures Thresholds

Thresholds that determine levels of good, fair, and poor are based on the average number of closures per mile per year within each of the nine identified statewide significant corridors by ADOT. The following thresholds represent statewide averages cross those corridors:

Good	< 0.26
Fair	> 0.26 & ≤ 1.53
Poor	V/C > 0.89

Directional Travel Time and Planning Time Index

In terms of overall mobility, the travel time index (TTI) is the relationship of the posted speed limit in a specific section of the corridor to the mean peak hour speed in the same location. The planning time index (PTI) is the relationship of the 5th percentile of the lowest mean speed to the posted speed limit in a specific section of the corridor. Using HERE data provided by ADOT, four time periods for each data point were collected throughout the day (AM Peak, Mid-Day, PM Peak, and Off-peak). Using the mean speeds and 5th percentile lowest mean speeds collected over 2013 for these time periods for each data location, four TTI and PTI calculations were made using the following formulas:

TTI = Posted Speed Limit/Mean Peak Hour Speed

PTI = Posted Speed Limit/5th Percentile Lowest Speed

The highest value of the four time periods calculation was defined as the TTI for that data point. The average TTI was calculated within each segment based on the number of data points collected. The value of the average TTI across each entry was used as the TTI for each respective segment within the corridor.

Data Entry for Directional TTI and PTI

1. Using the 'Congestion Metrics' file provided by ADOT, filter and sort column D on Sheet 1 to show only your corridor.
2. Using the 'Arizona_FHWA_Monthly_Static_File_Q22013' file, link the two spreadsheets together using the common TMC data column into a new combined file.
3. In the new combined file, associate each record to a segment based on location within the corridor using the Latitude/Longitude coordinates provided. Organize by direction within each segment.

Note: Each directional location will have four data records (AM Peak, Mid-day, PM Peak, Off Peak).

4. On tab 'PTI_TTI Calculations' in Mobility Index workbook, copy values from combined workbook to the columns A through I with the same headings.
5. Using the 'SpeedLimit' GIS file, identify the posted speed limit for each record location throughout each segment and input values into Column P (Speed_Limit) on the 'PTI_TTI_Calculations' tab in the Mobility Index workbook.
6. On tab 'PTI_TTI_Calculations' columns J through O should auto fill. Extend formulas as necessary based on the number of records for each segment.
7. On 'Mobility Index' tab, columns Y, Z, AA, and AB should auto fill based on values and ratings as indicated.

Multimodal Opportunities

Transit Dependency

2008-2012 U.S. Census American Community Survey tract and state level geographic data and attributes from the tables B08201 (Number of Vehicles Available by Household Size) and B17001 (Population in Poverty within the Last 12 Months) were downloaded with margins of error included from the Census data retrieval application Data Ferret. Population ranges for each tract were determined by adding and subtracting the margin of error to each estimate in excel. The tract level attribute data was then joined to geographic tract data in GIS. Only tracts within a one mile buffer of each corridor are considered for this evaluation.

Tracts that had a statistically significantly larger number of either people in poverty or households with only one or no vehicles available than the state average was considered potentially transit dependent.

Example: The state average for Zero or One Vehicles HHs is between 44.1% and 45.0%. Tracts which have the LOWER bound of their range above the UPPER bound of the state range definitely have a greater percentage of zero/one vehicle HHs than the state average. Tracts that have their UPPER bound beneath the LOWER bound of the state range definitely have a lesser percentage of zero/one vehicles HHs than the state average. All other tracts that have one of their bounds overlapping with the state average cannot be considered statistically significantly different because there is a chance the value is actually the same.

<u>Transit Dependency Rating Methodology</u>

Tracts with both zero and one vehicle household and population in poverty percentages below the statewide average

Tracts with either zero and one vehicle household OR population in poverty percentages within the statewide average

Tracts with both zero and one vehicle household and population in poverty percentages above the statewide average

In addition to transit dependency, the following attributes were added to the Multimodal Opportunities map based on available data.

1. Shoulder width throughout the corridor based on 'Shoulder Width' GIS dataset provided by ADOT.
2. Intercity bus routes
3. Multiuse paths within the corridor ROW if applicable

% Non SOV Trips

The percentage of non-single occupancy vehicle trips over distances less than 50 miles gives an indication of travel patterns along a section of the corridor that could benefit from additional multimodal options in the future.

<u>% Non-SOV Trips Data Entry</u>

1. Using the 2010 AZTDM2 file provided by ADOT, export your corridor model files to an excel workbook.
2. Copy values from output file and paste into appropriate columns with the same name on tab 'Non SOV Short Trips_raw.' Yellow highlighted cells will auto fill based on inputs. **Do not paste any values into yellow highlighted cells.**
3. On tab '2010' in the Mobility Index workbook, input Direction, ID, and SEG values associated with your corridor from the AZTDM2 output file. Organize by segment as shown in I-19 example file.
   Note: Copy formulas as needed based on number of records in each segment.
4. On tab '2010' Column E, J, K and L will auto fill based on raw data input.
5. On tab 'Mobility Index' Column AD will autofill and ratings will be assigned based conditional formatting to the appropriate threshold.
   Note: Thresholds will be finalized upon determination of statewide averages for Non-SOV trips. This data has been requested from ADOT and will be provided upon receipt.

<u>% Non-SOV Thresholds</u>
Thresholds that determine levels of good, fair, and poor are based on the % Non SOV trips within each of the nine identified statewide significant corridors by ADOT. The following thresholds represent statewide averages cross those corridors:

Good	≥ 17%
Fair	> 11% & ≤ 17%
Poor	< 11%

Safety Performance Area Calculation Methodologies

The Appendix summarizes the approach for developing the primary and secondary performance measures in the Safety Performance Area as shown in the following graphic.

Safety Index

To calculate the Safety Index, you will need to identify the fatal and incapacitating injury crashes that occur on each study corridor segment as well as on other roadway segments statewide that have similar operating environments. You will also need to determine segment lengths and average annual daily traffic (AADT) volumes for use in developing crash rates.

<u>Study Corridor Segments</u>

1. Start with the Excel spreadsheets provided by ADOT for crashes on the State Highway System in the years 2009-2013. These files are called 2009.xls, 2010.xls, 2011.xls, 2012.xls, and 2013.xls. These files should have multiple columns that start with Incident, Unit, and Person.
2. For each of the Excel spreadsheets, create a new shapefile in ArcGIS of the crash data by plotting the crash locations in ArcGIS using the 'Add XY Data' function and the IncidentLatitude and IncidentLongitude columns in the Excel spreadsheets.
3. Query the crash shapefiles on the Incident InjurySeverityDesc field to only display fatal and incapacitating injury crashes and on the UnitNumber to only display records with a unit number of "1". This results in one crash record for each fatal and incapacitating injury crash on the State Highway System.
4. Query the crash shapefiles on the IncidentOnroad field to only display fatal and incapacitating injury crashes on mainline segments (these typically are the roadway name in the cardinal direction and the roadway name with a zero after a space in the non-cardinal direction: e.g., I 040 and I 040 0) and to exclude crashes on ramps, frontage roads, and at interchanges (these typically have the roadway name with a one or two or series of numbers/letters at the end: e.g., I040 2 and I 040001G). Also, query the crash shapefiles on the IncidentCrossingFeature field to only display those crashes occurring along the study corridor based on the milepost limits of the corridor (e.g., M000 to M196). Visually inspect the selected crashes to confirm they are along the study corridor and make manual adjustments to the dataset if needed.
5. Determine how many fatal and incapacitating injury crashes occurred within each corridor segment for each analysis year and enter this information into the highlighted cells in Columns B and C that correspond to the corridor segments in the F + I Crash Analysis Summary tab in the Excel file named Safety_Index_Example_I-40_12-03-14.xlsx.

<u>Similar Operating Environments Statewide</u>

1. Identify what different "operating environments" (OEs) there are in the corridor by comparing the characteristics of the various corridor segments. Characteristics to consider include functional classification, number of lanes, rural vs. urban area, and AADTs. Each segment of a particular OE should have relatively similar characteristics, but it is important to not be so prescriptive that you end up with lots of different OEs on a single corridor. For illustrative purposes, on I-40 between milepost (MP) 0 and MP 196, two OEs were identified:
    a. Four-Lane Rural Freeways with Up to 20,000 AADT (corresponds to 12 I-40 segments)
    b. Four-Lane Urban Freeways with Up to 40,000 AADT (corresponds to 2 I-40 segments)
2. Identify segments on other roadways in the State Highway System that have the same OE by opening the Highway Performance Monitoring System (HPMS) database provided by ADOT in ArcGIS.
3. Combine the 'Lanes' feature class with the 'FuncClass' feature class by running the 'Identity' or 'Intersect' tools in ArcGIS Toolbox. If the polylines don't identically overlay, it may be necessary to use a tolerance. A tolerance of 5 feet seems to provide satisfactory results.
4. Combine the output of the prior step with the 'AADT' feature class using the same methodology described in the prior step for each analysis year (2009, 2010, 2011, 2012, and 2013). This results in five new feature classes – one for each analysis year.
5. For the illustrative I-40 corridor, create two separate feature classes based on the prior step new classes by isolating '4 Lane Rural Principal Interstate with AADT <= 20,000' and '4 Lane Urban Principal Interstate with AADT <= 40,000'. The function code (FuncCode) for Rural Principal Interstate is 1 and the function code for Urban Principal Interstate is 11. This results in a total of ten new feature classes – one rural and one urban for each analysis year. The following is a list of the fields from the original datasets used to perform the query.
    a. Lanes feature class = LANES
    b. FuncClass feature class = FuncCode
    c. AADT = VALUE_NUME

   Some of the field names may be truncated or changed in the process of combining the data. If there are more than two OEs for the corridor, there will be more new feature classes.
6. Create selection sets that combine the fatal and incapacitating crash data sets by year developed in steps 1-3 of the Study Corridor Segments methodology write-up with the rural and urban feature class data sets created in the prior step using the 'Select By Location' tool in ArcGIS. Use a tolerance of one mile to select all of the crashes. Visually inspect the selected crashes to confirm they are along the correct OE roadway segments. For roadways with multiple OEs, crashes may have been selected beyond the endpoint of a line for the desired OE and instead along the line of a different OE. If this occurs, manually remove the extraneous crashes from the selection.

7. Query the selection sets on the IncidentOnroad field to only display fatal and incapacitating injury crashes on mainline segments of the desired OE segments (these typically are the roadway name in the cardinal direction and the roadway name with a zero after a space in the non-cardinal direction: e.g., I 040 and I 040 0) and to exclude crashes on ramps, frontage roads, and at interchanges (these typically have the roadway name with a one or two or series of numbers/letters at the end: e.g., I040 2 and I 040001G). Visually inspect the selected crashes to confirm they are along the desired OE segments of the State Highway System and make manual adjustments to the dataset if needed.
8. Determine how many fatal and incapacitating injury crashes occurred within each similar OE segment statewide for each analysis year and enter this information into the highlighted cells in Columns B and C that correspond to the respective similar statewide OE segments in the F + I Crash Analysis Summary tab.

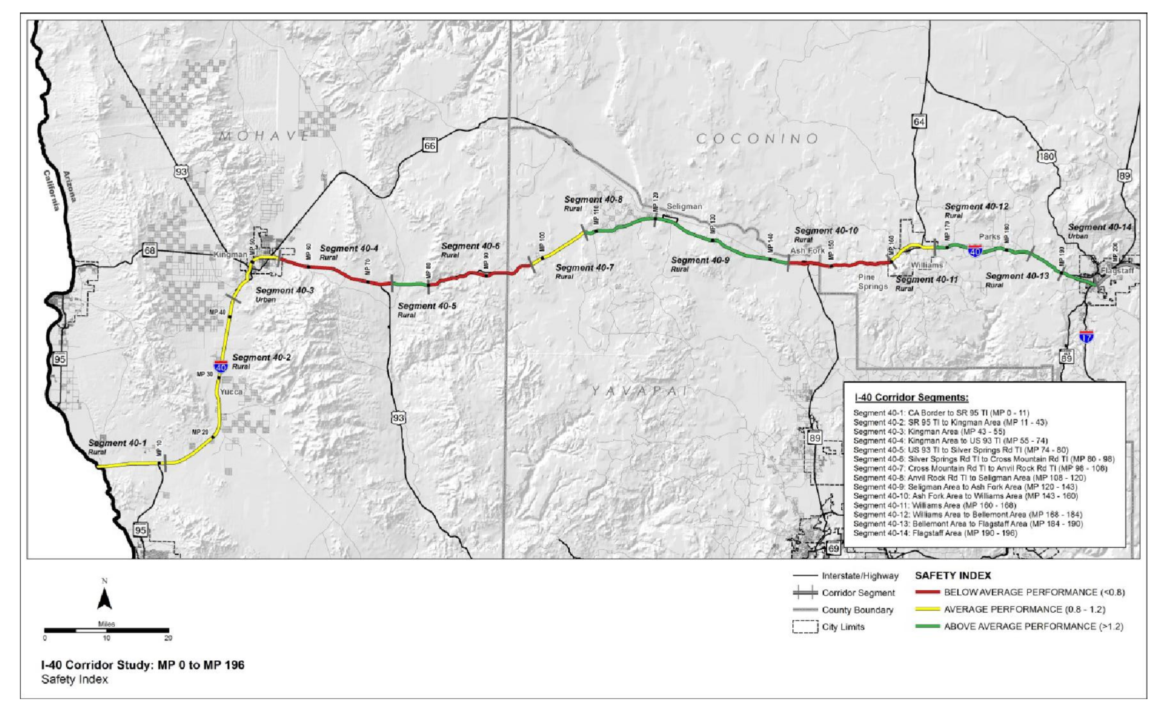
<u>Segment Lengths and AADTs</u>

1. Determine the length of each corridor segment from the Similar Operating Environments Statewide selection sets that include HPMS geometric information and enter this information into the highlighted cells in Column E that correspond to the corridor segments in the F + I Crash Analysis Summary tab. Segment length data can be found in the field called SECTION_LE – the “recalculate geometry” function should be performed on the segment length data before utilizing the data as segment lengths can change when files are combined.
2. Determine the average AADT of each corridor segment by summing the AADTs within a particular corridor segment and dividing that sum by the number of AADT data points in the corridor segment. Any segments that have a value of 0 should be excluded from the summary and average calculation. The AADTs for the corridor segments can be extracted from the Similar Operating Environments Statewide selection sets that include HPMS AADT information. Enter this information into the highlighted cells in Column F that correspond to the corridor segments in the F + I Crash Analysis Summary tab.
3. Determine the total length of the segments included in each Similar Operating Environments Statewide selection set for each year. Total segment lengths may vary by year due to AADTs varying by year, which can change which segments are included or excluded in the OE. Enter this information into the highlighted cells in Column E that correspond to the similar OE statewide segments in the F + I Crash Analysis Summary tab. Again, segment length data can be found in the field called SECTION_LE – the “recalculate geometry” function should be performed on the segment length data before utilizing the data as segment lengths can change when files are combined.
4. Determine the average AADT of the segments included in each Similar Operating Environments Statewide selection set for each year. Any segments that have a value of 0 should be excluded from the summary and average calculation. Enter this information into the highlighted cells in Column F that correspond to the similar OE statewide segments in the F + I Crash Analysis Summary tab.

<u>Safety Index Calculation</u>

1. Once the fatal and incapacitating injury crashes, segment lengths, and AADTs on corridor segments and similar OE statewide segments have been entered into the highlighted cells in the F + I Crash Analysis Summary tab, existing formulas will use that data to calculate crash frequency and rate values and ranges of average values for these parameters in the F + I Crash Analysis Summary tab.
2. In the Safety Index tab of the Excel file named Safety_Index_Example_I-40_12-03-14.xlsx, existing formulas will combine the crash frequency and rate values to create a safety index for each corridor segment that compares the performance of a particular segment to the performance of similar OE statewide segments. To keep all Safety index values at the same scale, a cap should be set that puts the midpoint of the average equidistant between the cap and zero. In the case of the I-40 corridor between MP 0 and MP 196, the cap is 2.0.
3. Safety index values are categorized (and colorized) as performing Above Average (green color), Average (yellow color), or Below Average (red color) through existing formulas and conditional formatting in the Safety Index tab based on the statewide average being plus or minus one standard deviation from the mean statewide average for each of the five years for similar OE statewide segments.
4. Create a map showing the Safety Index by color for each segment.

Segment	Fatal Crashes 2009-2013	Incapacitating Injury Crashes 2009-2013	Segment Length (mi)	Average AADT Volume 2009-2013	Safety Index (SI)	Safety Index Description (SI < 0.8 = Below Average SI >=0.8 & <=1.2 = Average SI >1.2 = Above Average)
Segment 40-1	4	6	11.0	13,521	0.82	Average
Segment 40-2	8	29	32.0	14,067	1.07	Average
Segment 40-3	7	12	12.0	23,606	0.98	Average
Segment 40-4	10	15	19.0	19,538	0.67	Below Average
Segment 40-5	1	3	6.0	13,791	1.65	Above Average
Segment 40-6	7	15	18.0	11,989	0.69	Below Average
Segment 40-7	3	7	10.0	12,054	0.89	Average
Segment 40-8	0	13	12.0	12,306	2.00	Above Average
Segment 40-9	3	23	23.0	12,501	1.58	Above Average
Segment 40-10	10	15	17.0	13,308	0.50	Below Average
Segment 40-11	2	6	8.0	14,622	1.13	Average
Segment 40-12	1	11	16.0	15,707	2.00	Above Average
Segment 40-13	1	3	6.0	19,344	1.93	Above Average
Segment 40-14	1	3	6.0	18,024	2.00	Above Average



SHSP Emphasis Areas

ADOT's recently updated Strategic Highway Safety Plan (SHSP) identifies several emphasis areas. The top five SHSP emphasis areas relate to the following driver behaviors:

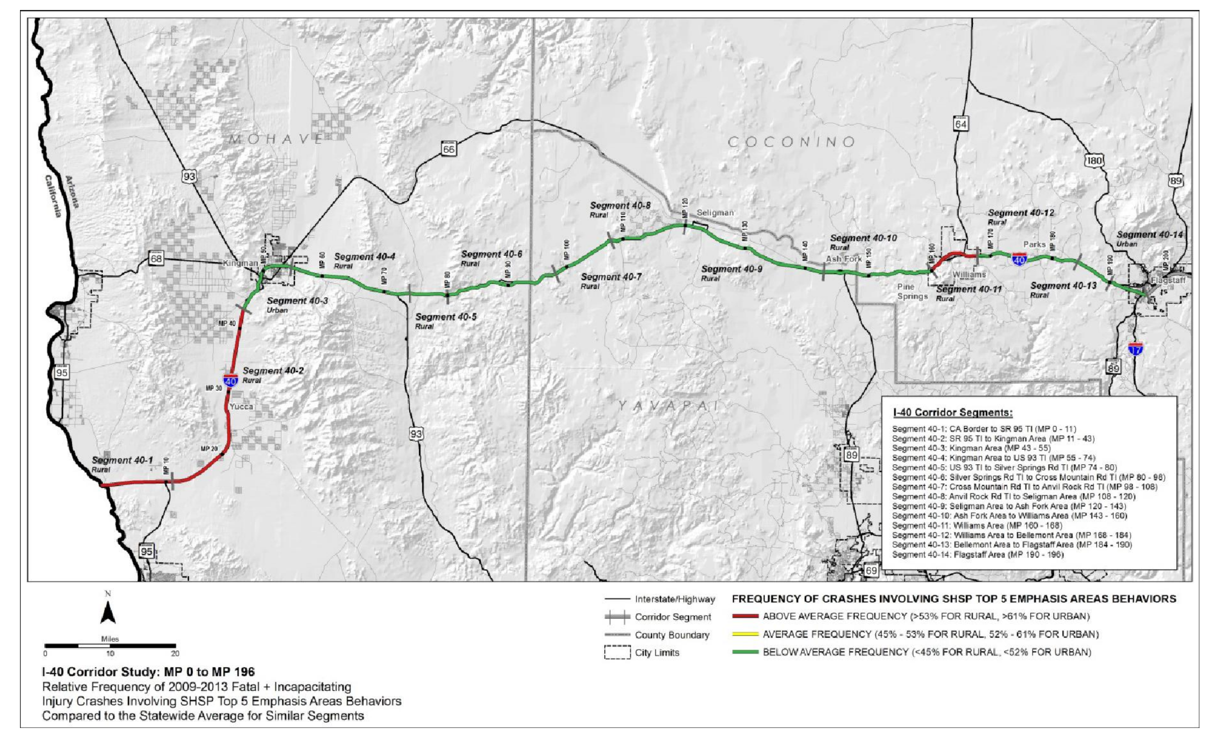
- Speeding/Aggressive Driving
- Impaired Driving
- Lack of Restraint Usage
- Lack of Motorcycle Helmet Usage
- Distracted Driving

To determine how well particular corridor segments are performing in these five emphasis areas, the relative frequencies of the aforementioned driver behaviors at the corridor segment level can be compared to similar OE segments statewide. To avoid large swings in performance due to one or two crashes where the sample size is small, the five emphasis areas behaviors are combined to identify crashes that exhibit one or more of the emphasis areas behaviors.

1. Using the fatal and incapacitating injury crash selection set developed for corridor segments, run a query that identifies fatal and incapacitating injury crashes that contain one or more of the field attributes listed below:
    a. Speeding/Aggressive Driving – PersonViol codes of Exceeded Lawful Speed, Followed Too Closely, Unsafe Lane Change, Passed in No-Passing Zone, Other Unsafe Passing
    b. Impaired driving – PersonPh_2 code of Physical Impairment, PersonPh_3 code of Fell Asleep/Fatigued, PersonPh_4 code of Alcohol, PersonPh_5 code of Drugs, PersonPh_6 code of Medication
    c. Lack of Restraint Usage – PersonSafe code of None Used
    d. Lack of Motorcycle Helmet Usage – PersonSafe code of None Used (already included in Lack of Restraint Usage)
    e. Distracted driving – PersonViol codes of Inattention/Distraction and Electronic Communication Device
2. Using the fatal and incapacitating injury crash selection set developed for similar OE statewide segments, run a query that identifies fatal and incapacitating injury crashes that contain one or more of the field attributes listed above.
3. Enter the sum of the fatal and incapacitating injury crashes that exhibit one or more of the aforementioned emphasis areas behaviors for both the individual corridor segments and similar OE statewide segments into the highlighted cells in Column L in the F + I Crash Analysis Summary tab. Existing formulas use that data to calculate the percentage of total fatal and incapacitating injury crashes involving the emphasis areas behaviors and ranges of average values for these parameters in the F + I Crash Analysis Summary tab.
4. In the Crash % Indices tab of the Excel file named Safety_Index_Example_I-40_12-03-14.xlsx, existing formulas and conditional formatting compare the performance of a particular segment to the performance of similar OE statewide segments for the emphasis areas behaviors and categorize (and colorize) segments as performing Above Average (green color), Average (yellow color), or Below Average (red color) based on the statewide average being plus or minus one standard deviation from the mean statewide average for each of the five years for similar OE statewide segments.
5. Create a map showing the comparative frequency of fatal and incapacitating injury crashes that exhibit one or more of the aforementioned SHSP emphasis areas behaviors by color for each segment.

Segment Operating Environment Type	Total Statewide Fatal + Incapacitating Injury Crashes	Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	% of Total Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors			
			Annual Average (Mean)	Standard Deviation (SD)	Lower Limit of Average (Mean - SD)	Upper Limit of Average (Mean + SD)
Rural	646	317	49%	4%	45%	53%
Urban	146	82	57%	5%	52%	61%

Segment Operating Environment Type	Corridor Segment	Segment Fatal + Incapacitating Injury Crashes	Segment Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	% of Segment Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	Frequency of Segment Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors
Rural	Segment 40-1	10	7	70%	Above Average
Rural	Segment 40-2	37	23	62%	Above Average
Urban	Segment 40-3	19	7	37%	Below Average
Rural	Segment 40-4	25	5	20%	Below Average
Rural	Segment 40-5	4	1	25%	Below Average
Rural	Segment 40-6	22	8	36%	Below Average
Rural	Segment 40-7	10	2	20%	Below Average
Rural	Segment 40-8	13	3	23%	Below Average
Rural	Segment 40-9	26	9	35%	Below Average
Rural	Segment 40-10	25	11	44%	Below Average
Rural	Segment 40-11	8	6	75%	Above Average
Rural	Segment 40-12	12	4	33%	Below Average
Rural	Segment 40-13	4	1	25%	Below Average
Urban	Segment 40-14	4	0	0%	Below Average



Crash Unit Types

ADOT's SHSP also identifies emphasis areas that relate to the following unit or entity type involved in crashes:

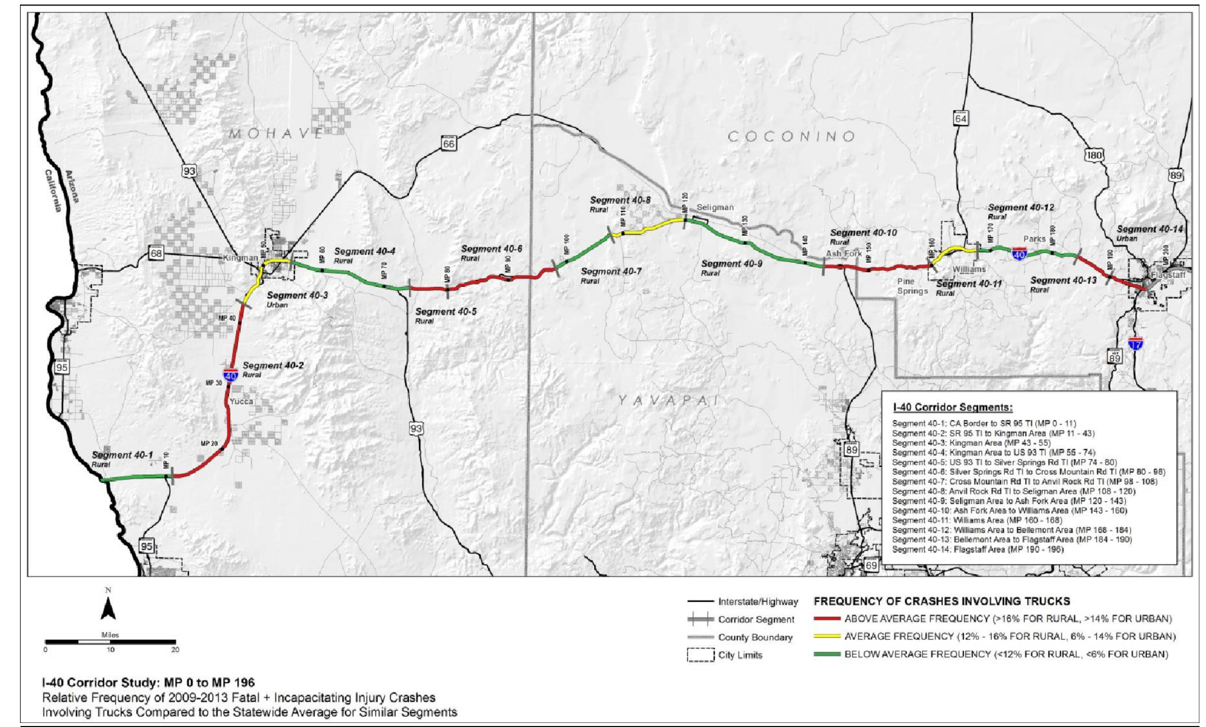
- Heavy Vehicles (Trucks)
- Motorcycles
- Non-Motorized Travelers (pedestrians and bicyclists)

To determine how well particular corridor segments are performing in these emphasis areas, the relative frequencies of the aforementioned crash unit types at the corridor segment level can be compared to similar OE segments statewide. To avoid large swings in performance due to one or two crashes where the sample size is small, these emphasis areas should only be mapped if the sample size is sufficiently large.

1. Follow the same steps as the SHSP Emphasis Areas methodology except run a query that identifies fatal and incapacitating injury crashes that contain one or more of the field attributes listed below:
    a. Truck-involved crashes – all UnitBodyStyleDesc codes that start with Truck
    b. Motorcycle-involved crashes – all UnitBodyStyleDesc codes that start with Motorcycle
    c. Non-motorized traveler-involved crashes – PersonTypeDesc codes of Pedestrian or Pedalcyclist
2. Enter the sum of the fatal and incapacitating injury crashes that exhibit one or more of the aforementioned crash unit types for both the individual corridor segments and similar OE statewide segments into the highlighted cells in the F + I Crash Analysis Summary tab. In the illustrative I-40 corridor, only truck-involved crashes have a sufficiently large sample size so this is the only crash unit type emphasis area to include in the F + I Crash Analysis Summary tab (Column O) and to map in this case. In fact, even for truck-involved crashes, only a few segments have a sufficiently large sample size, so this needs to be considered when conducting further evaluation on corridor segment performance. Existing formulas use the crash unit type data to calculate the percentage of total fatal and incapacitating injury crashes involving trucks and ranges of average values for this parameter in the F + I Crash Analysis Summary tab.
3. In the Crash % Indices tab of the Excel file named Safety_Index_Example_I-40_12-03-14.xlsx, existing formulas and conditional formatting compare the performance of a particular segment to the performance of similar OE statewide segments for truck-involved crashes and categorize (and colorize) segments as performing Above Average (green color), Average (yellow color), or Below Average (red color) based on the statewide average being plus or minus one standard deviation from the mean statewide average for each of the five years for similar OE statewide segments.
4. Create a map showing the comparative frequency of fatal and incapacitating injury crashes that involve trucks by color for each segment.

Segment Operating Environment Type	Total Statewide Fatal + Incapacitating Injury Crashes	Fatal + Incapacitating Injury Crashes Involving Trucks	% of Total Fatal + Incapacitating Injury Crashes Involving Trucks: Annual Average (Mean)	Standard Deviation (SD)	Lower Limit of Average (Mean - SD)	Upper Limit of Average (Mean + SD)
Rural	646	90	14%	2%	12%	16%
Urban	146	15	10%	4%	6%	14%

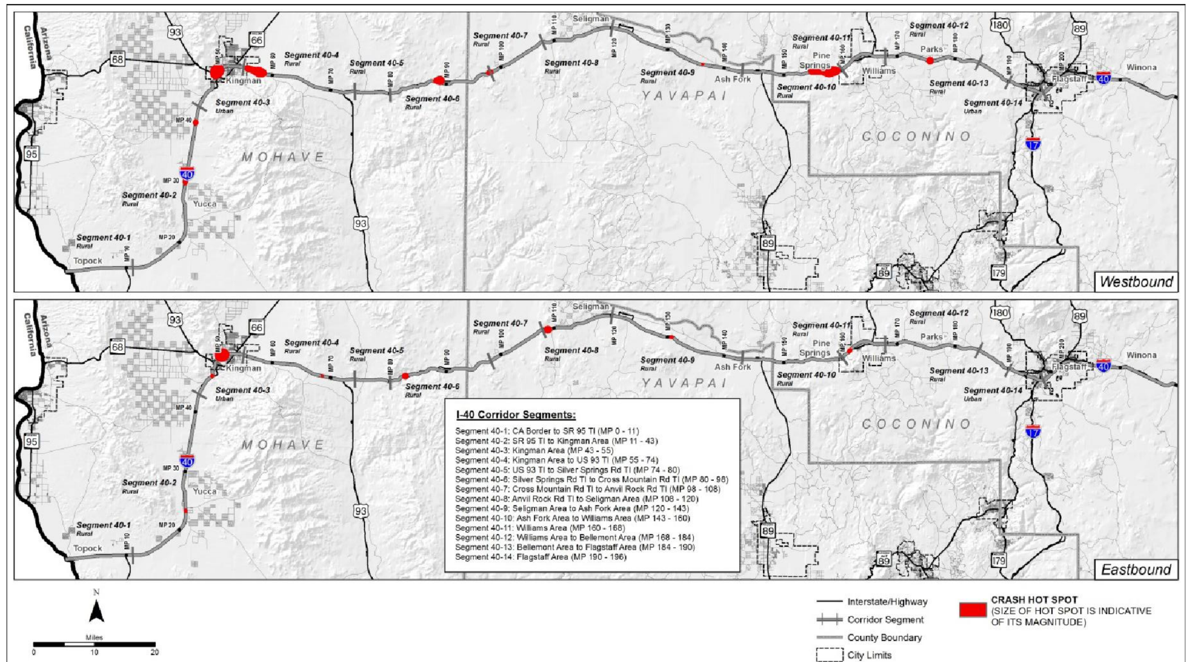
Segment Operating Environment Type	Corridor Segment	Segment Fatal + Incapacitating Injury Crashes	Segment Fatal + Incapacitating Injury Crashes Involving Trucks	% of Segment Fatal + Incapacitating Injury Crashes Involving Trucks	Frequency of Segment Fatal + Incapacitating Injury Crashes Involving Trucks
Rural	Segment 40-1	10	1	10%	Below Average
Rural	Segment 40-2	37	9	24%	Above Average
Urban	Segment 40-3	19	2	11%	Average
Rural	Segment 40-4	25	2	8%	Below Average
Rural	Segment 40-5	4	1	25%	Above Average
Rural	Segment 40-6	22	4	18%	Above Average
Rural	Segment 40-7	10	1	10%	Below Average
Rural	Segment 40-8	13	2	15%	Average
Rural	Segment 40-9	26	3	12%	Below Average
Rural	Segment 40-10	25	4	16%	Above Average
Rural	Segment 40-11	8	1	13%	Average
Rural	Segment 40-12	12	0	0%	Below Average
Rural	Segment 40-13	4	1	25%	Above Average
Urban	Segment 40-14	4	1	25%	Above Average



Safety Hot Spots

A "hot spot" analysis identifies abnormally high concentrations of crashes. This analysis of fatal and incapacitating injury crashes along the study corridor by direction of travel involves the following steps:

1. Using the fatal and incapacitating injury crashes selection set developed previously for the Safety Index for corridor segments, separate the crashes by direction of travel using the field named UnitTravelDirectionDesc.
2. In ArcGIS Toolbox, open the 'Kernel Density' tool. The input file is the fatal and incapacitating injury crashes selection set by direction file. The population field should be set to 'NONE'. For the output cell size, a value of 50 feet is recommended. For the search radius, a value of 10,560 feet (2 miles) is recommended. The above parameters may need to be changed based on the scale of the map.
3. Create a map showing the results as a raster dataset.
4. Remove the lower classification categories from the display by setting the symbology colors of these classifications to 'Null' such that the classification categories still in the display show only high concentration areas of crashes.
5. Make the remaining higher classification categories all display the same red color by setting the color of these classifications to RGB 245 0 0.



I-40 Corridor Study: MP 0 to MP 196
2009 - 2013 Crash Hot Spot
(Fatal and Incapacitating Injury Crashes Only)

Freight Performance Area Calculation Methodologies

The Appendix summarizes the approach for developing the primary and secondary performance measures in the Freight Performance Area as shown in the following graphic.

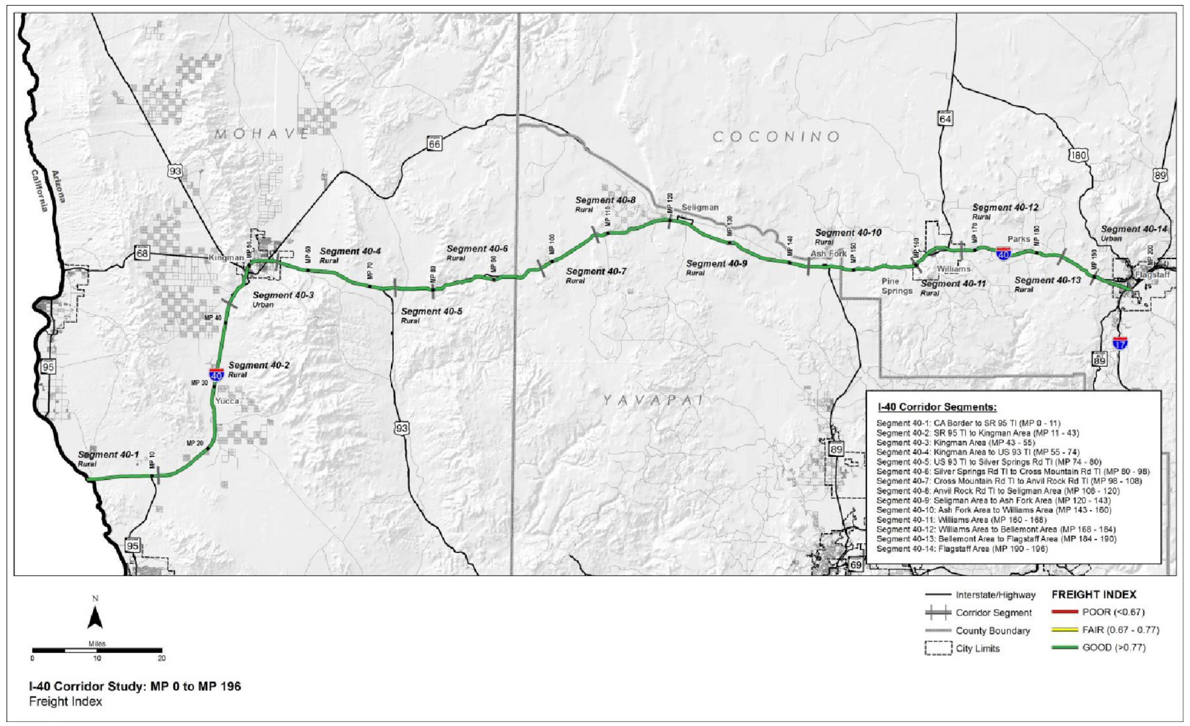
Freight Index

1. Open the file called Freight_Index_Example_I-40_12-02-14.xlsx. This file contains several tabs. The “Freight Performance Area” tab is a summary of the various performance measure results on I-40 for the Freight Performance Area .
2. In the “Arizona_FHWA_Monthly_Static_Fil” tab, identify the TMCs (data collection sites) that correspond to the desired corridor. TMCs with a “P” denote positive direction of travel (north or east) and TMCs with a “N” denote negative direction of travel (south or west). Note: Some TMCs will not have a corresponding TMC in the opposite direction of travel. It is important not to treat a missing value as a zero in the following calculations.
3. Using the latitude/longitude values for the TMCs in the “Arizona_FHWA_Monthly_Static_Fil” tab and GIS, determine which TMCs apply to which corridor segment. Note: TMCs have a segment length that likely does not coincide with a corridor segment boundary so it is necessary to assign each TMC segment to the corridor segment that contains the majority of the TMC segment length.
4. In the “Congestion Metrics.xlsx Sheet1” tab, isolate the data to only show the desired TMCs.
5. Create a new “Speed Limit” column that assigns the speed limit of each TMC based on the speed limit information provided in the “SpeedLimit” tab. This is shown as column Z in the “Sheet1 with calculations” sample tab.
6. Create a new “Assumed truck free-flow speed” column that is the lower value of the speed limit column or 65 miles per hour (mph). This “cap” of 65 mph accounts for governors that trucks often have that restrict truck speeds to no more than 65 mph. This is shown as column AB in the “Sheet1 with calculations” sample tab.
7. Create a new “Trucks_PTI” column that divides the “Assumed truck free-flow speed” column (column AB in the “Sheet1 with calculations” tab) by the “trucks_P05” 5th percentile speed column (column X in Sheet1). This creates the truck planning time index (TPTI) and is shown as column AG in the “Sheet1 with calculations” sample tab.
8. Create a new “Trucks_Peak PTI” column that lists the maximum TPTI value that corresponds to each TMC using the MAX function in Excel. There are typically four different TPTIs for each TMC: AM Peak, Mid Day Peak, PM Peak, and Off Peak. Note: one or more TPTI value may be missing so it is important that the MAX function has the correct cell range for each TMC. This is shown as column AK in the “Sheet1 with calculations” sample tab.
9. Create a new “Segment Average Trucks_Peak PTI” column that lists the average TPTI value that corresponds to each corridor segment using the AVERAGE function in Excel. This is shown as column AQ in the “Sheet1 with calculations” sample tab.
10. Create a new “Combined Average Peak TPTI” column that averages the TPTI in each direction of travel. This is shown as column BP in the “Sheet1 with calculations” sample tab.
11. Create a new Freight Index column that inverts the “Combined Average Peak TPTI” values by segment. This is shown as column BS in the “Sheet1 with calculations” sample tab.
12. Categorize the Freight Index values by segment with Poor < 0.67, Fair 0.67-0.77, and Good > 0.77. Colorize the Freight Index values by segment using the color red for Poor, yellow for Fair, and green for Good. This is shown as column B in the “Freight Performance Area” sample tab.

Segment	Freight Index (1/TPTI)	Freight Index Description
Segment 40-1	0.88	Good
Segment 40-2	0.95	Good
Segment 40-3	0.87	Good
Segment 40-4	0.81	Good
Segment 40-5	0.95	Good
Segment 40-6	0.86	Good
Segment 40-7	0.95	Good
Segment 40-8	0.91	Good
Segment 40-9	0.93	Good
Segment 40-10	0.83	Good
Segment 40-11	0.88	Good
Segment 40-12	0.94	Good
Segment 40-13	0.95	Good
Segment 40-14	0.91	Good

Freight Index (FI)	
Poor	< 0.67
Fair	0.67-0.77
Good	> 0.77

13. Create a map showing the Freight Index categories by color for each segment.



Directional TPTI

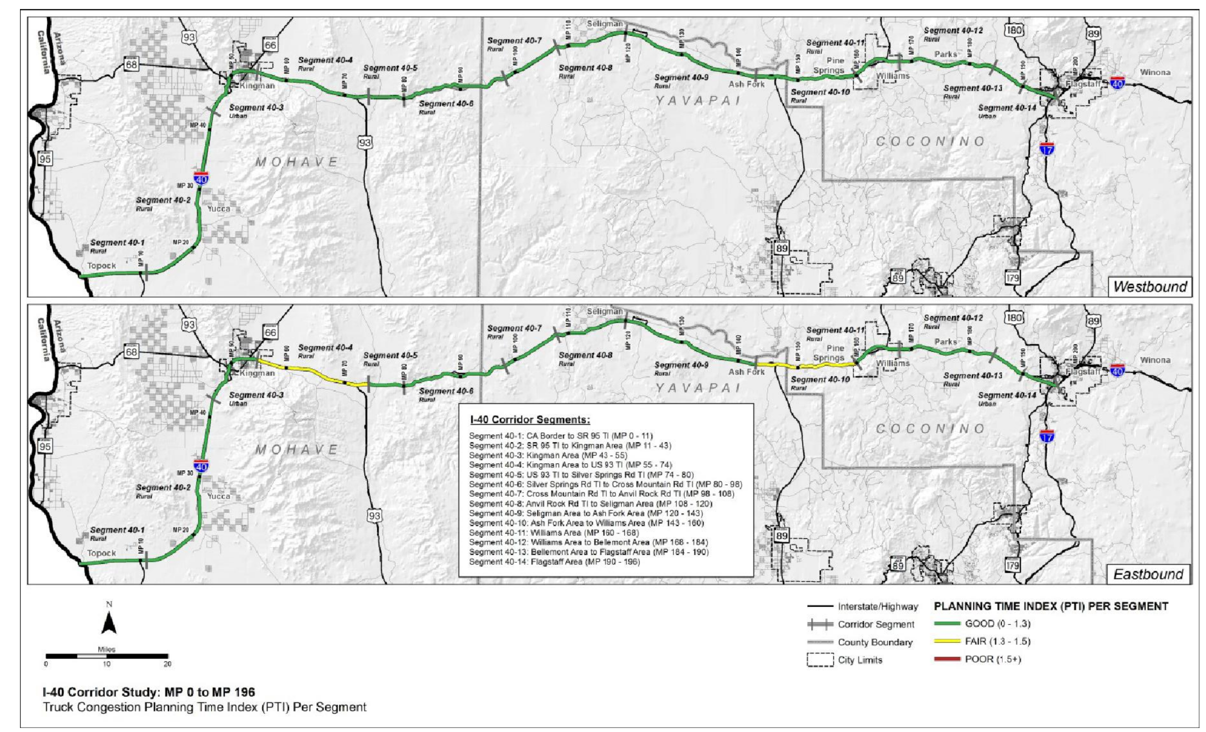
1. Follow steps 1-9 of the Freight Index methodology to calculate the Directional TPTI.
2. Categorize the Directional TPTI values by segment with Poor > 1.5, Fair 1.3-1.5, and Good < 1.3. Colorize the Directional TPTI values by segment using the color red for Poor, yellow for Fair, and green for Good. This is shown as columns K and L in the "Freight Performance Area" sample tab.

Segment	Westbound Average TPTI	Eastbound Average TPTI
Segment 40-1	1.08	1.20
Segment 40-2	1.05	1.07
Segment 40-3	1.09	1.22
Segment 40-4	1.17	1.31
Segment 40-5	1.08	1.03
Segment 40-6	1.05	1.29
Segment 40-7	1.04	1.07
Segment 40-8	1.12	1.08
Segment 40-9	1.09	1.07
Segment 40-10	1.10	1.32
Segment 40-11	1.09	1.17
Segment 40-12	1.06	1.06
Segment 40-13	1.05	1.07
Segment 40-14	1.15	1.06

TPTI

Good	< 1.3
Fair	1.3-1.5
Poor	>1.5

3. Create a directional map showing the Directional TPTI by color for each segment.



Directional TTTI

1. Follow steps 1-6 of the Freight Index methodology.
2. Create a new "Trucks_TTI" column that divides the "Assumed truck free-flow speed" column (column AB in the "Sheet1 with calculations" tab) by the "trucks_mean" average speed column (column N in Sheet1). This creates the truck travel time index (TTTI) and is shown as column AE in the "Sheet1 with calculations" sample tab.
3. Create a new "Trucks_Peak TTI" column that lists the maximum TTTI value that corresponds to each TMC using the MAX function in Excel. There are typically four different TPTIs for each TMC: AM Peak, Mid Day Peak, PM Peak, and Off Peak. Note: one or more TPTI value may be missing so it is

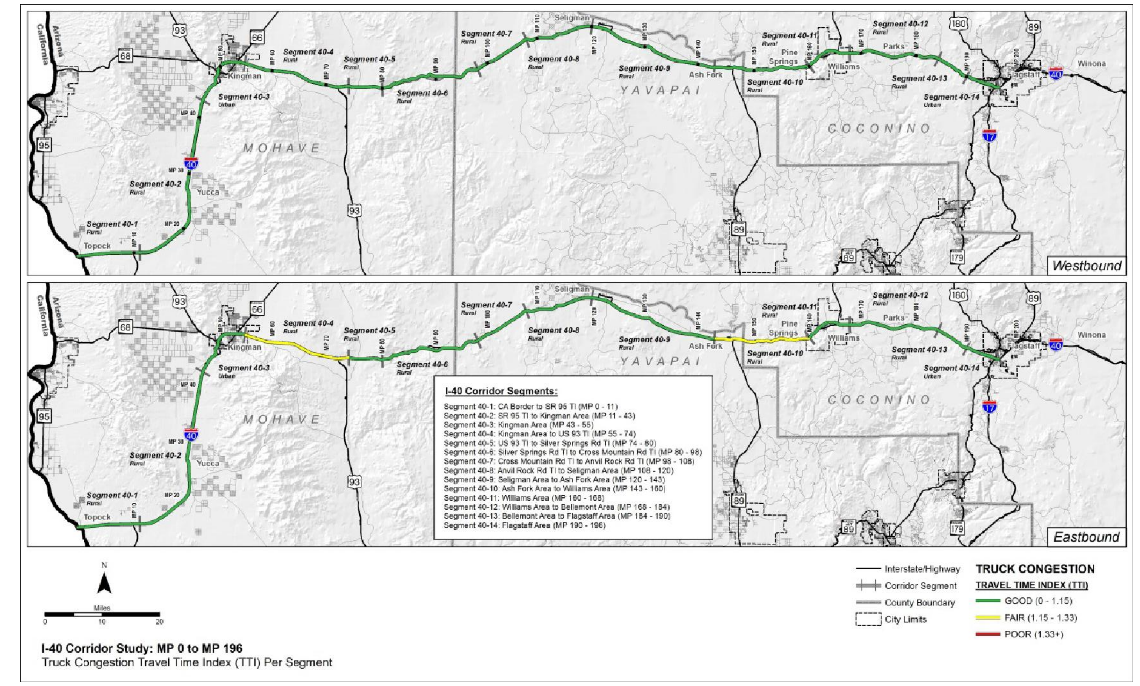
important that the MAX function has the correct cell range for each TMC. This is shown as column AI in the “Sheet1 with calculations” sample tab.

4. Create a new “Segment Average Trucks_Peak TTI” column that lists the average TTTI value that corresponds to each corridor segment using the AVERAGE function in Excel. This is shown as column AO in the “Sheet1 with calculations” sample tab.
5. Create new directional TTTI columns, “Westbound Average TTTI” and “Eastbound Average TTTI”. This is shown as columns BI and BJ in the “Sheet1 with calculations” sample tab.
6. Categorize the Directional TTTI values by segment with Poor > 1.33, Fair 1.15-1.33, and Good < 1.15. Colorize the values by segment using the color red for Poor, yellow for Fair, and green for Good. This is shown as columns F and G in the “Freight Performance Area” sample tab.

Segment	Westbound Maximum TTTI	Eastbound Maximum TTTI
Segment 40-1	1.04	1.11
Segment 40-2	1.01	1.03
Segment 40-3	1.03	1.11
Segment 40-4	1.08	1.19
Segment 40-5	1.02	1.00
Segment 40-6	1.00	1.14
Segment 40-7	1.00	1.03
Segment 40-8	1.06	1.05
Segment 40-9	1.04	1.02
Segment 40-10	1.04	1.17
Segment 40-11	1.04	1.08
Segment 40-12	1.03	1.03
Segment 40-13	1.02	1.03
Segment 40-14	1.08	1.03

TTTI	
Good	< 1.15
Fair	1.15-1.33
Poor	> 1.33

7. Create a directional map showing the Directional TTTI by color for each segment.



HCRS Road Closures

1. Filter the “HCRS Statewide Full Closures” tab to display the closure data corresponding to the desired corridor for the years 2009-2013.
2. Confirm by looking at the hwy_at_mp (column R) and the hwy_to_mp (column S) that the closure milepost limits include at least part of one or more of the corridor segments. For any closures that go beyond the corridor limits, revise the milepost limits to match the corridor limits.
3. Sort the data by milepost using hwy_at_mp (column R).
4. Insert a new column for each milepost in the corridor and label it accordingly. This is shown as columns Z through HM in the “Example I-40 Closure Analysis” sample tab.
5. Mark a “1” in each milepost column wherever that milepost was included within the limits of each closure (each row). Closures occurring between mileposts should be assigned to the higher milepost. Closures occurring exactly at a milepost should be assigned to the adjacent milepost. For example, a closure at milepost 2.3 would be marked in the milepost 3 column, as would a closure at milepost 2.0.
6. Insert a new column that sums the “1” values in each row and as a check compare this to the “closure length” column in the “HCRS Statewide Full Closures” tab. The two columns should match. If they don’t, confirm that the “1” values have been input correctly.
7. Insert a new column for each milepost in the corridor and label it accordingly. Create a new formula that takes the clearance time in minutes from the “clearance_mins” column and converts it to hours and places that value in each cell that contains a “1” from step 5. This is shown as columns PK through WX in the “Example I-40 Closure Analysis” sample tab.
8. Insert a new column that sums the hours of clearance times in each row and as a check compare this to the “hours of closure duration accounting for length” column in the “HCRS Statewide Full Closures” tab. The two columns should match. If they don’t, confirm that the formulas have been input correctly.

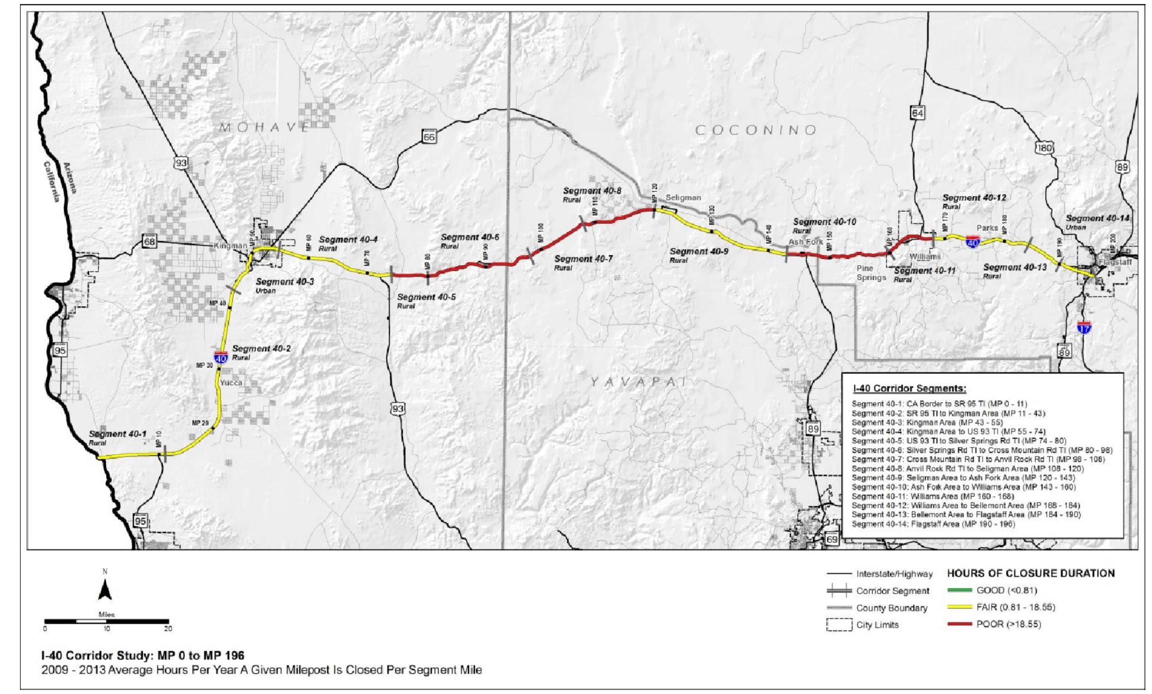
9. Identify the total closure duration in each corridor segment by summing the hours of clearance times values in each milepost for each segment. This should be done bi-directionally (both directions of travel combined) although it can also be done for each direction separately, if desired, based on the “hwy_dir_descr” column in the “HCRS Statewide Full Closures” tab. Note that some closures may apply to both directions so they need to be counted in each of the separate directions if values for each direction are calculated separately. This is shown in cells PQ258 through QF264 in the “Example I-40 Closure Analysis” sample tab.
10. Divide the total closure duration per segment by the length of each segment and by the number of years of data to get the average hours per year a given milepost is closed per segment mile in each segment. This is shown in cells B51 through O56 in the “Example I-40 Closure Summary” sample tab.
11. Input the statewide mean and standard deviation of the average hours per year a given milepost is closed per segment mile. These statewide values are shown in column R in the “Example I-40 Closure Summary” sample tab. Add one standard deviation to the statewide mean to get an upper limit for an average scaling category. Subtract one standard deviation from the statewide mean to get a lower limit.
12. Categorize the average hours per year a given milepost is closed per segment mile in each segment with Poor > upper average limit, Fair between upper and lower average limits, and Good < lower average limit. Colorize the values by segment using the color red for Poor, yellow for Fair, and green for Good. This is shown as column P in the “Freight Performance Area” sample tab.

Segment	Average Hours Per Year a Given Milepost Is Closed Per Segment Mile
Segment 40-1	1.01
Segment 40-2	3.64
Segment 40-3	3.89
Segment 40-4	6.47
Segment 40-5	21.09
Segment 40-6	20.86
Segment 40-7	19.52
Segment 40-8	19.52
Segment 40-9	15.86
Segment 40-10	21.13
Segment 40-11	20.39
Segment 40-12	18.08
Segment 40-13	15.97
Segment 40-14	14.79

Average Hours Per Year a Given Milepost Is Closed Per Segment Mile

Good	< 0.81
Fair	0.81-18.55
Poor	>18.55

13. Create a map showing the average hours per year a given milepost is closed per segment mile by color for each segment.



Truck Restrictions

1. Geolocate the existing truck height restrictions in the corridor using the data provided by the ADOT Intermodal Transportation Department Engineering Permits Section.
2. Create a map showing the truck height restrictions, with different symbols for locations where ramps exist that allow the restriction to be avoided and for locations where ramps do not exist and the restriction cannot be avoided.